Instruments

THE MAGAZINE OF

Measurement and Control

Vol. 18
JAN. 1945
No. 1

COPY TO L. OF C. JAN 27 1945

INCLUDING *Aviation Instruments*

BAROMETERS
Mercurial

CONTROLLERS
Flow
Humidity
pH
Liquid Level
Pressure
Temperature
Vacuum

FLOW INSTRUMENTS
Controllers
Indicators
Integrators
Meters
Recorders

GAGES, RECORDING
Pressure
Temperature
Vacuum

HYDROMETERS

HYGROMETERS
Wet & Dry Bulb
Thermometers

LIQUID LEVEL
Controllers
Indicators
Recorders

MERCURIAL GAGES
Absolute Pressure
Mercurial Vacuum

MOISTURE METERS
Grains, Tobacco,
Wood, Granular
Material

OIL TESTING INSTRUMENTS

POTENTIOMETERS
Controlling
Indicating
Recording

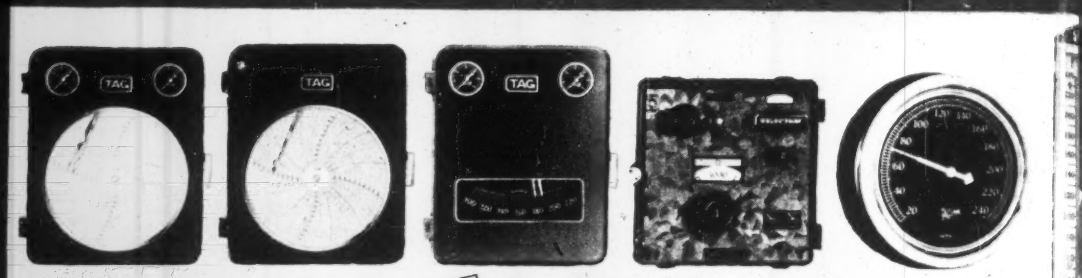
PYROMETERS
Controlling
Indicating
Recording
Resistance
Thermoelectric

RECORDERS
Electric
Flow
Humidity
pH
Hygrometer
Liquid Level
Pressure
Psychrometers
Temperature
Time-Operation
Vacuum

STEAM TRAPS

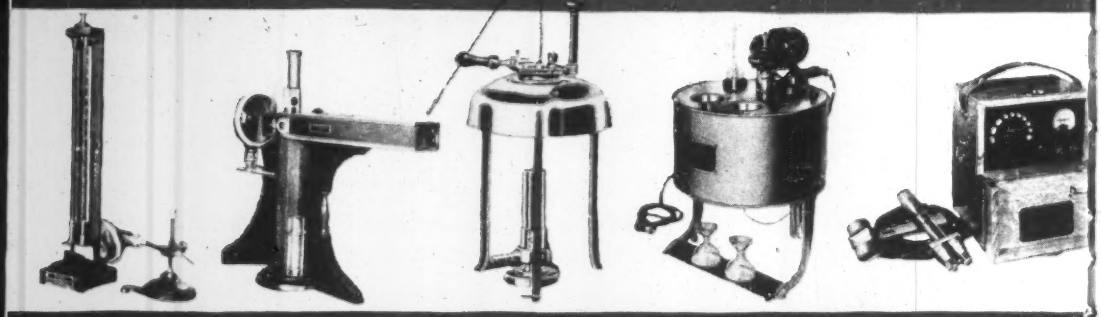
THERMOMETERS
Chemical
Dial
Electric
Expansion Stem
Indicating
Industrial
Recording
Resistance

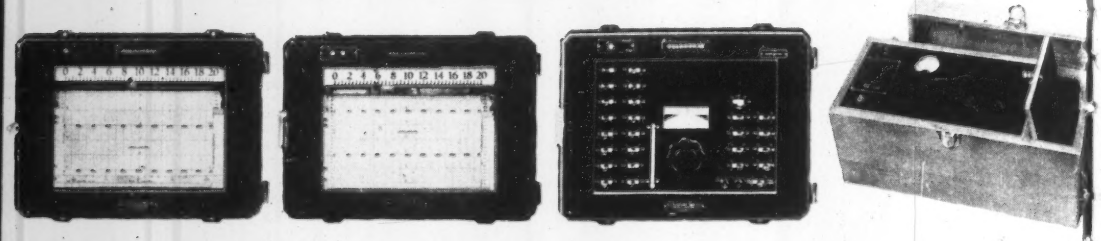
VALVES
Diaphragm
Reducing
V-Port
Three-Way



TAG

TAG Instruments are guarding a thousand production fronts . . . in synthetic rubber, chemicals, explosives, catalytic cracking, aeroplane testing, ordnance and food fields. And additional thousands of TAG Instruments are entrusted with special duties across the Seven Seas. Check the list at the left for the TAG Instrument to help you score your production Victory in 1945.





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for the 5th time

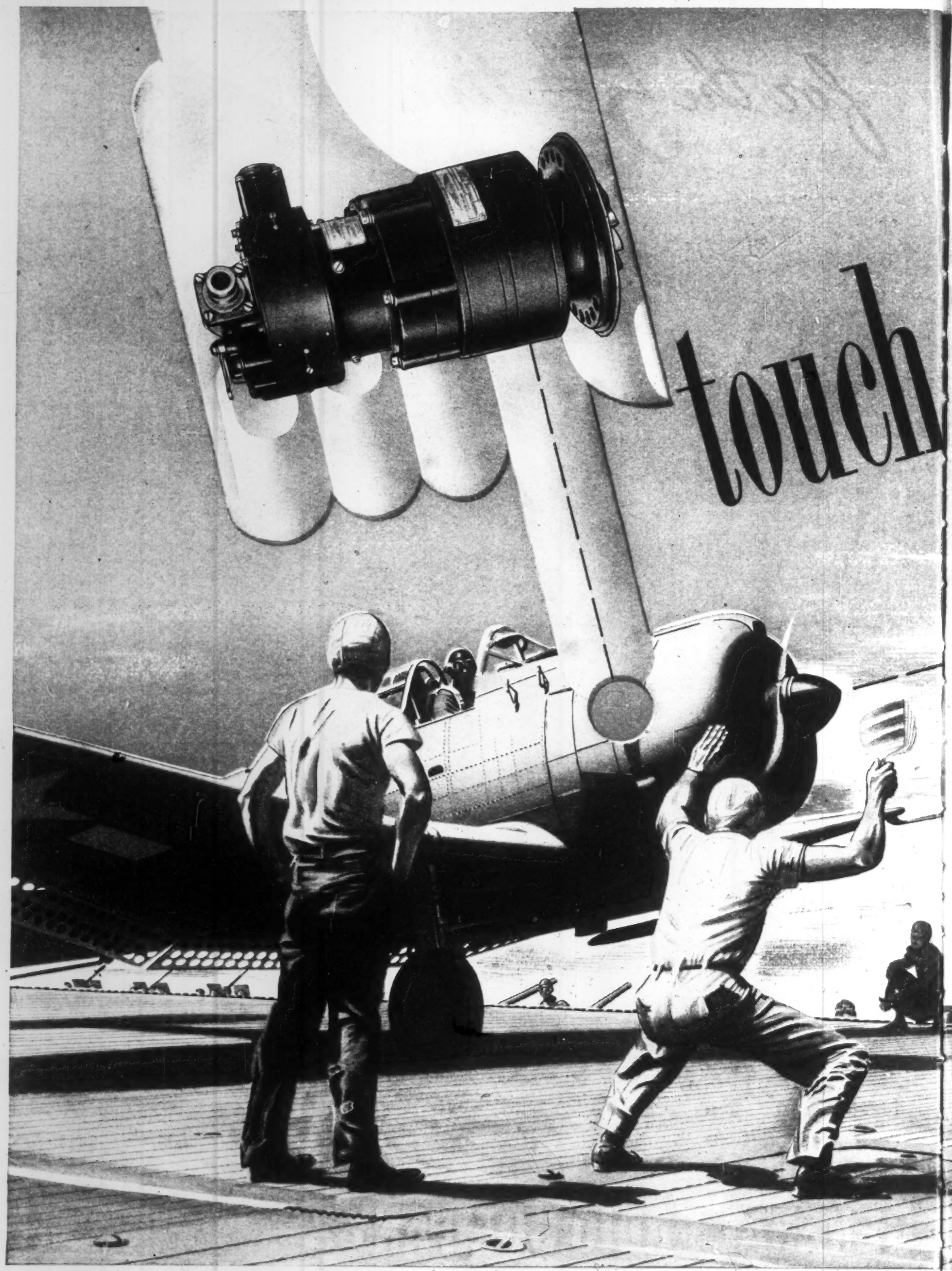
GENERAL RADIO was granted the coveted Army-Navy "E" Production Award for the fifth time in December of last year. G-R is one of very few in the electronic industry to receive this honor five times.

The production of precision electrical test equipment is a highly specialized business, demanding maintenance of close tolerances in all inspection, manufacturing and calibrating operations. Constant and close supervision by highly trained personnel is required to produce equipment of the precision and reliability of G-R instruments.

In order to meet the greatly increased production called for by the war, G-R has expanded to its limit, both in space and in personnel. We have subcontracted machining operations to several local firms; we have transferred our entire VARIAC production to leased space in another building; we have obtained considerable space in another building where we have contracted for a large number of war-time workers under our own foremen; we have let out the complete manufacture of several instruments to other manufacturers; we have turned over the design, drawings and models of several critical instruments to other manufacturers for their exclusive use.

G-R is proud that it has been able to meet the urgent production requirements of the war effort. It is equally grateful that the substantial contributions from its Development and Engineering Departments, through many thousands of hours of consulting engineering on secret war projects, have directly assisted in the solution of technical problems of the greatest urgency.

GENERAL RADIO COMPANY Cambridge 39, Massachusetts
NEW YORK CHICAGO LOS ANGELES


touch.

257
86

...and go!

Buy More War Bonds and Stamps

"Enemy aircraft approaching!" . . . and it's *touch and go* for the flattop fighters! Out where a delay of seconds could sink the ship, Jack & Heintz starters are famous for sure-fire performance. And wherever *touch* and *go* starting is vital . . . in Arctic cold or tropic heat or desert sands . . . these starters are pitting terrific stamina against the toughest battle conditions.

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These improvements . . . and others like them in the automatic pilot, in flight instruments, generators and retraction motors . . . are traceable to two distinct Jack & Heintz assets: an engineering staff that begins where usual thinking stops; and manufacturing techniques and revolutionary methods that set completely new standards in precision production.

So valuable in war, this ability . . . these methods hold great new things in store for peacetime aviation. Watch for the fulfillment of their promise.

Jack & Heintz, Inc., Cleveland, Ohio, manufacturers of Aircraft Engine Starters, Generators, Gyro Pilots, Gyro Flight Instruments, Magnetos, Motors.

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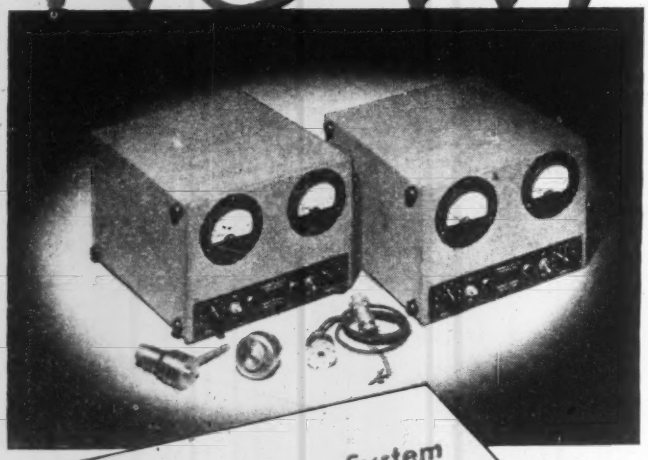

A New Carrier System for Static and Dynamic Pressure Measurements

• Here's a new improved carrier system for measurement of static and dynamic pressures, strain, vibrations, accelerations, velocities, dynamic travel, angular position, clearances between moving parts and other measurements.

This carrier system can be used with primary elements also manufactured and designed by Trimount, for studies of: steam, gasoline, and Diesel engine cylinder head pressures; manifold pressures; supercharger and blower pressures; fuel system pressures; air scoop pressures; aircraft landing gear shock loads; dynamic pressures in pumps and compressors; turbine blade elongations, etc. A cathode ray oscillograph, a recording oscillograph, or other recording or indicating equipment can be used with the Trimount Carrier System.

The system is available in two series, one making use of the modulated carrier wave principle, while the other type employs a discriminator circuit. Frequency ranges are as high as 10,000 CPS. The power supply and oscillator are small, compact and lightweight and can be furnished in any number of channels required.

Write for detailed information on these new, improved instruments.

ELECTRONICS DIVISION

TRIMOUNT Instrument COMPANY

37 WEST VAN BUREN STREET, CHICAGO 5, ILLINOIS

Instruments

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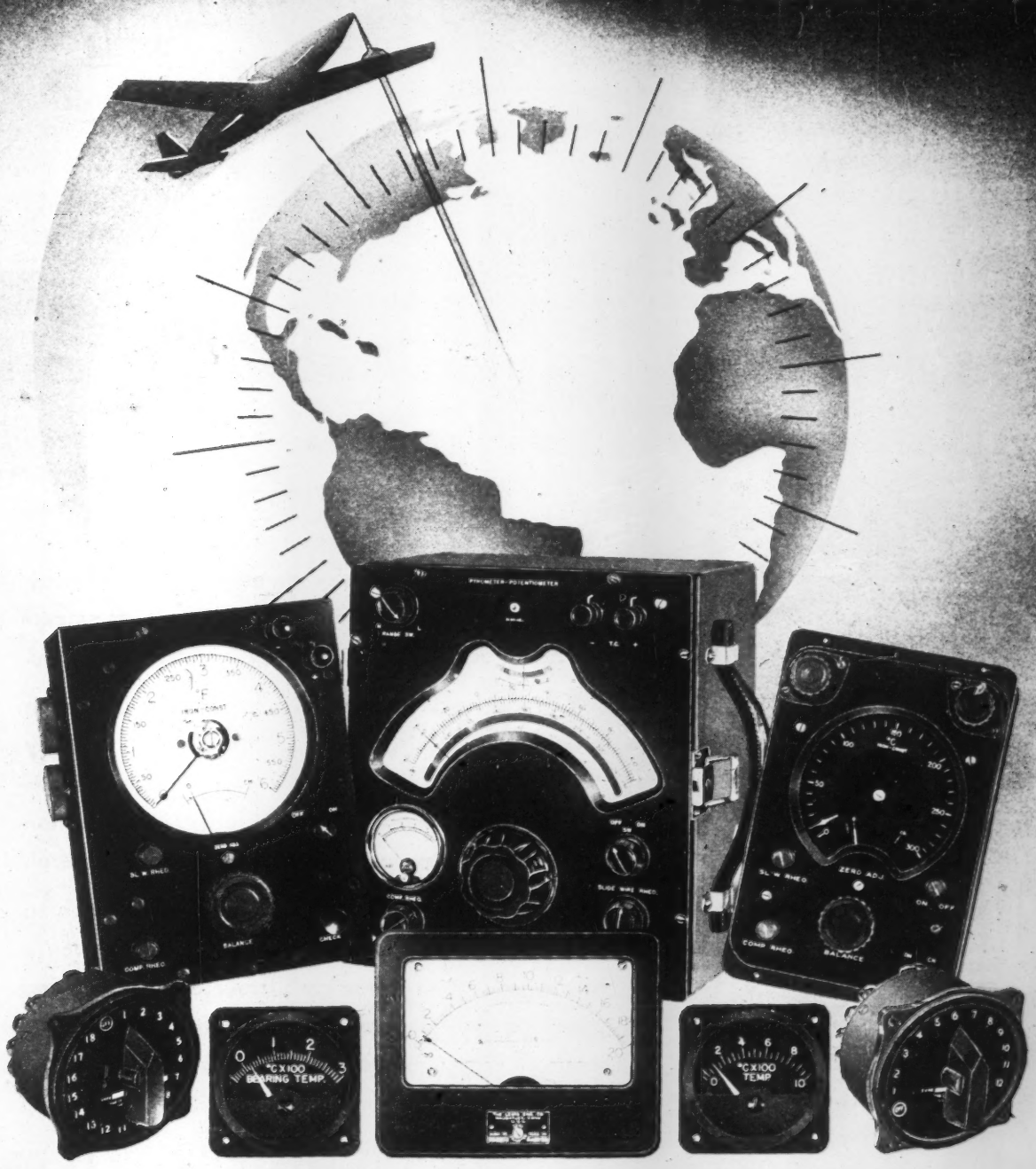

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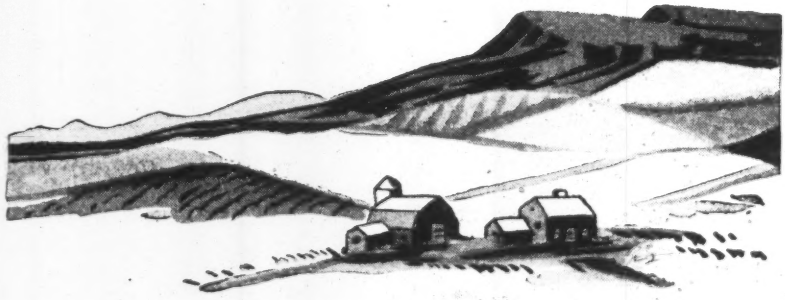
...Hardly had man learned to fly than he began to feel the urgency of the need to communicate between ground and plane.

Radio headsets are one of C. T. & E. Division's contributions to aviation communications in World War II.



One of the first successful attempts in such two-way contact was accomplished with equipment designed and manufactured by *Connecticut Telephone & Electric.*

Since the early days of the telephone, our people have been identified with progress in communications. Today the principles of communications have applications of the greatest importance to industry, in connection with product development and production control.

Our developmental engineers also have much to offer to industrial executives seeking to produce a better product at lower cost. If our engineering and production facilities might tie in with your plans, we shall be happy indeed to talk with you.

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GREAT AMERICAN INDUSTRIES, INC.

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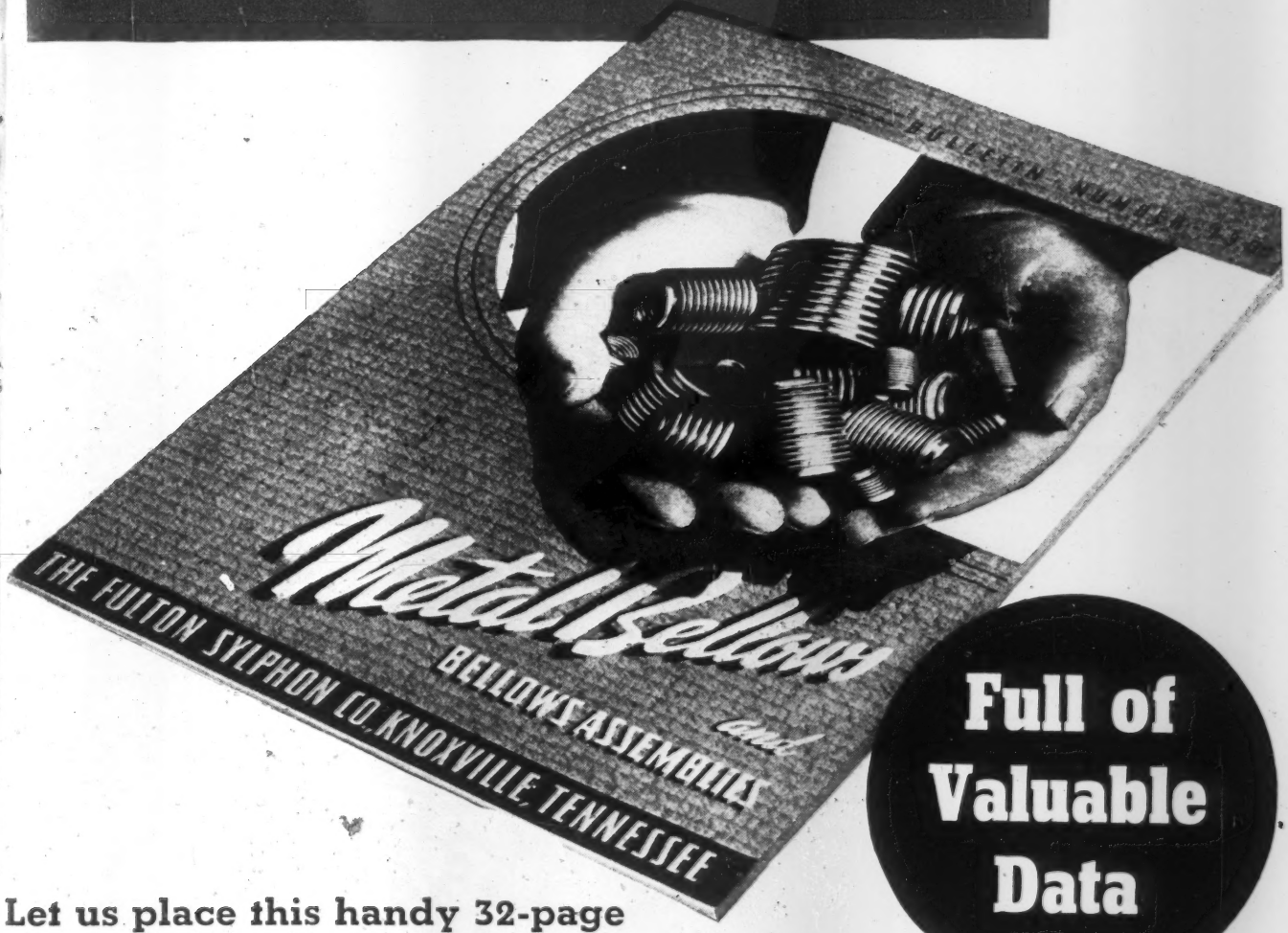
TELEPHONIC SYSTEMS • SIGNALLING EQUIPMENT • ELECTRONIC DEVICES • ELECTRICAL EQUIPMENT • HOSPITAL AND SCHOOL COMMUNICATIONS AND SIGNALLING SYSTEMS • IGNITION SYSTEMS

Just say the word...*



Full of Valuable Data

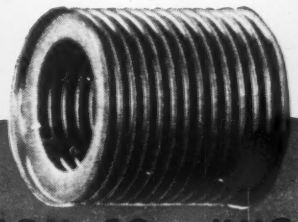
Let us place this handy 32-page reference book on your desk without charge

ALL ABOUT BELLOWS, bellows assemblies, and bellows devices. How they are made, what they do, life expectancies, etc. Complete information on physical characteristics, sizes, metals, assemblies, applications, etc., etc. Included are many useful time-saving tables—equivalents, conversion equations, temperature conversions, and physical data on approved charges; also pages of drawings detailing design and construction, together with photographs of special bellows and interesting assemblies.

*Write on your letterhead: "YES, I'd like to receive a copy of the new Fulton Sylphon Bulletin AE-1300."

NEW MOVIE—"The Story of Metal Bellows" is available to interested executives and organizations.

FULTON SYLPHON



TEMPERATURE CONTROLS — BELLOWS — BELLOWS ASSEMBLIES

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known Performance

for destinations known or unknown

Today, our electrical equipment encircles the globe; some serving at Greenland's ice-cap or in Kiska's fogs . . . others stewing in the swamps of a Pacific atoll.

With the destinations of war-products totally unknown, manufacturers logically have preferred "building-in" WESTONS on their control panels. They know that a WESTON will perform dependably *anywhere* . . . that there is sound reason behind WESTONS acceptance as the *international standard.*

And tomorrow, with equipment reaching known markets, instrument preferences will remain unchanged. For while human life no longer will be at stake, *reputations will.* So manufacturers will continue to "build-in" the instruments which consistently tell-the-truth . . . to build broader market acceptance and customer good-will, and assure highest efficiency from the machines which bear their name.

- Laboratory Standards
- Precision DC and AC Portables
- Instrument Transformers
- Sensitive Relays
- DC, AC, and Thermo Switchboard and Panel Instruments
- Specialized Test Equipment
- Light Measurement and Control Devices
- Exposure Meters
- Aircraft Instruments
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Weston

WESTON ELECTRICAL INSTRUMENT CORPORATION
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FOR OVER 55 YEARS LEADERS IN ELECTRICAL MEASURING EQUIPMENT

wherever a tube is used . . .

for example:

COMBUSTION CONTROL

An abnormal increase in the density of smoke passing through a boiler breeching means a reduction of heat, loss of efficiency, increase in fuel consumption, and probably violation of smoke control ordinances. The electronically operated Worner Combustion Supervisor detects such conditions, turns in an audible or visible alarm, and sets in motion the mechanism that will bring about efficient combustion.

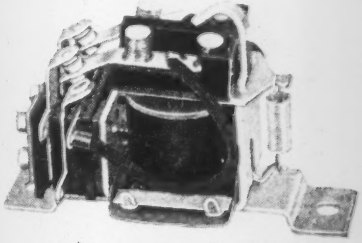
Control Unit

THERE'S A JOB FOR *Relays* BY GUARDIAN

The "Combustion Control Supervisor," made by Worner Electronic Devices of Chicago, is a photo-cell system that responds to any predetermined degree of smoke density. To avoid "false alarms" resulting from momentary puffs of smoke, it is equipped with a time delay feature.

Worner's specified that the three relays used in this system must be sensitive but not delicate; that they require no adjustment; and that they meet Underwriter's requirements.

Guardian engineers developed the Series 155 D.C. relay as the answer to these specifications. This is a compact, sturdy, easily mounted unit with constant spring tension on the contacts. It is widely used on remote selection devices and other low voltage applications. Copper slug time delays up to .05 seconds on attract and 0.15 seconds on release are available. Coils for operation on any voltage up to 230 volts D.C. For further information write for Series 155 bulletin.



Series 155 D.C. Relay

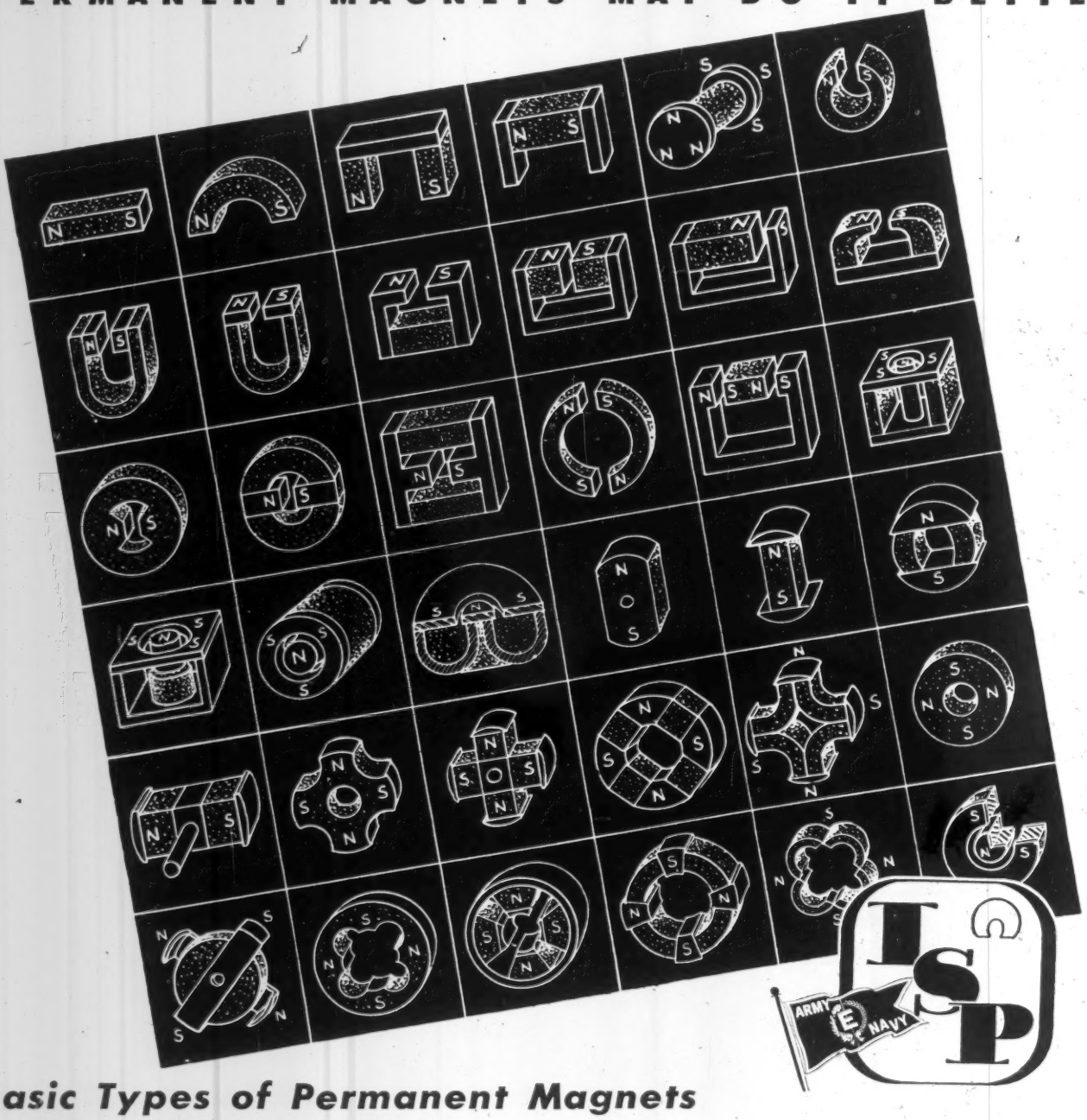
Consult Guardian whenever a tube is used —however—Relays by Guardian are NOT limited to tube applications, but are used wherever automatic control is desired for making, breaking, or changing the characteristics of electrical circuits.

GUARDIAN ELECTRIC

1638-A W. WALNUT STREET CHICAGO 12, ILLINOIS

A COMPLETE LINE OF RELAYS SERVING AMERICAN WAR INDUSTRY

PERMANENT MAGNETS MAY DO IT BETTER



Basic Types of Permanent Magnets

The thirty-six representative forms of permanent magnets shown above are adaptable to an infinite number of variations and uses. We have already made over 23,000 applications. Most of such applications are required to do some job which can be done better by magnetism than by other force, and are designed and engineered for this specific purpose. Permanent magnets are today making possible many mechanical and physical operations on implements of war which no other form of energy could actuate.

To determine the type of magnet for any industrial need calls for exceptional experience and research training in magnetics. As exclusive manufacturers of permanent magnets for over thirty-four years, this company has pioneered many advances in magnetic technology. Our technical and engineering staff can help you to solve your problems in magnetization. Write for consultation . . . and ask for a copy of our informative article, "*Permanent Magnets Have Four Major Jobs*," from which the above illustration is taken.

★ THE INDIANA STEEL PRODUCTS COMPANY ★

6 NORTH MICHIGAN AVENUE • CHICAGO 2, ILLINOIS

•

Specialists in Permanent Magnets Since 1910

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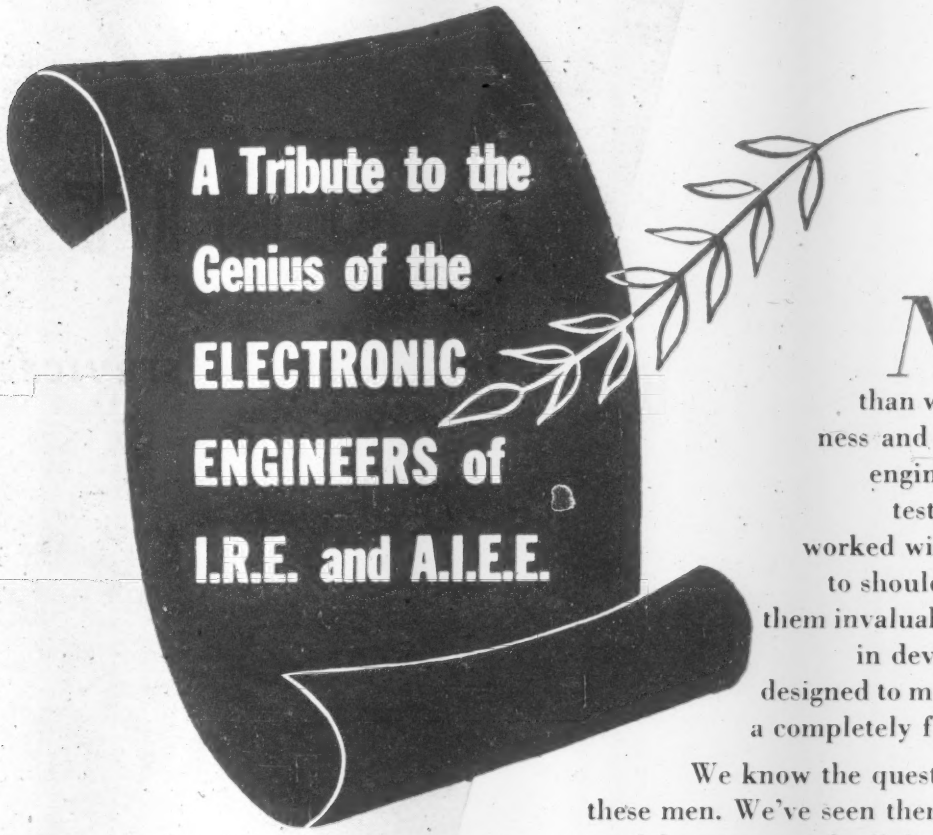

Nobody knows better than we do the resourcefulness and vision of electronic engineers. As builders of test equipment, we've worked with them, shoulder to shoulder. We've found them invaluable collaborators in devising apparatus designed to make electronics a completely foolproof tool.

We know the questing spirit of these men. We've seen them come into our laboratory, and all but turn the place upside down, diagramming, inspecting, or checking equipment aimed at perfecting the performance of electronics. Quality control is their fetish.

We can say that with authority. Because as makers of test equipment, quality control is our objective.

So when we pay tribute to the genius of electronic engineers, we know whereof we speak.

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Division of Sherron Metallic Corporation

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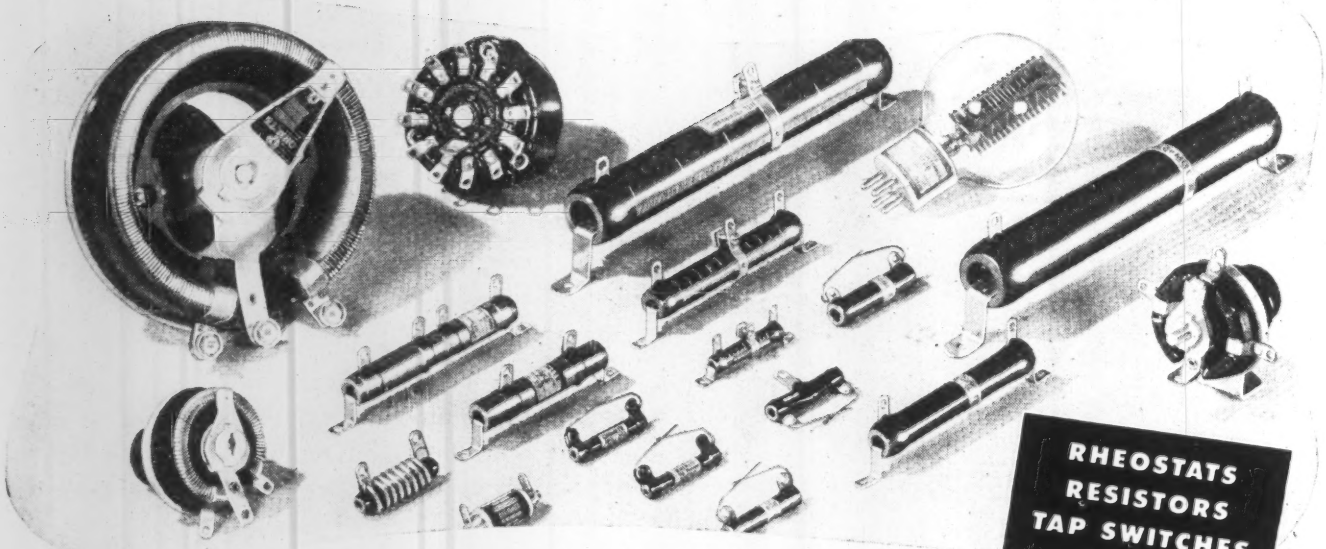

RHEOSTATS
RESISTORS
TAP SWITCHES
CHOKES

Designed and Built to Withstand

SHOCK
VIBRATION
TEMPERATURE EXTREMES
HUMIDITY
ALTITUDE

● Because they are so consistently reliable in actual service . . . Ohmite Rheostats, Resistors, Chokes and Tap Switches have become *"the control engineer's control units."*

Shown here are a few of the many types extensively used in military and industrial equipment. The wide variety of types and sizes in stock or special units provides a ready and exact answer to most applications.

In designing for war or postwar, let Ohmite experience help you.

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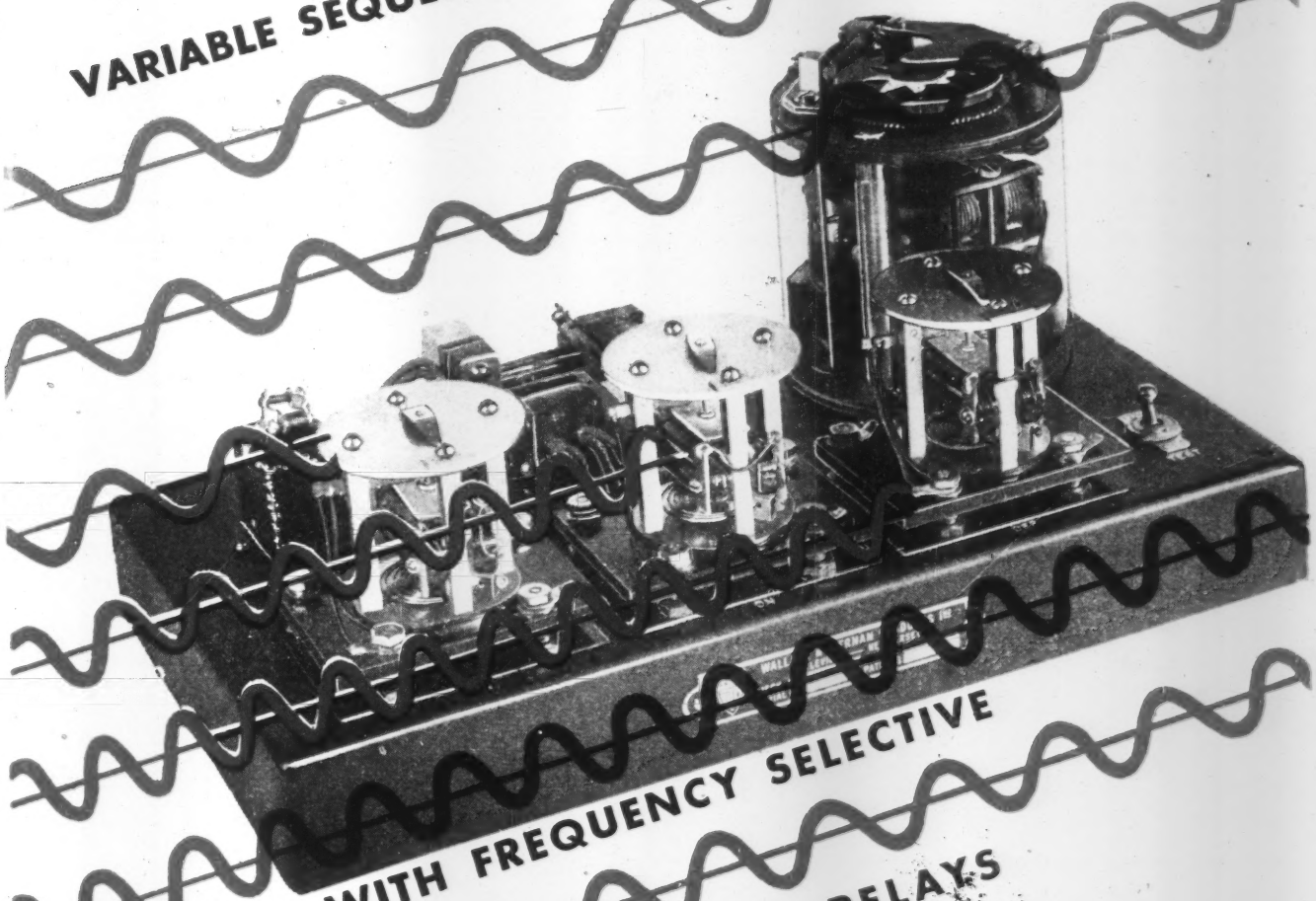
Be Right with **OHMITE**

RHEOSTATS • RESISTORS • TAP SWITCHES

VARIABLE SEQUENCE CONTROL



WITH FREQUENCY SELECTIVE TORSIONAL RELAYS

Lighting systems – radio transmitters – ventilating equipment – telephone circuits and a multitude of other operations must often be controlled from a remote point in varying sequence. Of itself remote control – even in varying sequence – is no insurmountable obstacle. Physical or economic factors, however, often dictate the use of only a single conductor of radio carrier wave circuit as the control medium. Such control is possible only if the operation-selective device possesses high sensitivity and critical reponse. The W&T Torsional Relay – stable over a wide range of ambient temperature and pressure – was developed to fulfill this specific requirement.

W&T Torsional Relays provide low cost, dependable variable sequence control which can be made completely automatic with the addition of W&T monitoring units.

ARMY E NAVY

WALLACE & TIERNAN PRODUCTS, INC.

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Higher THAN A PLANE CAN FLY

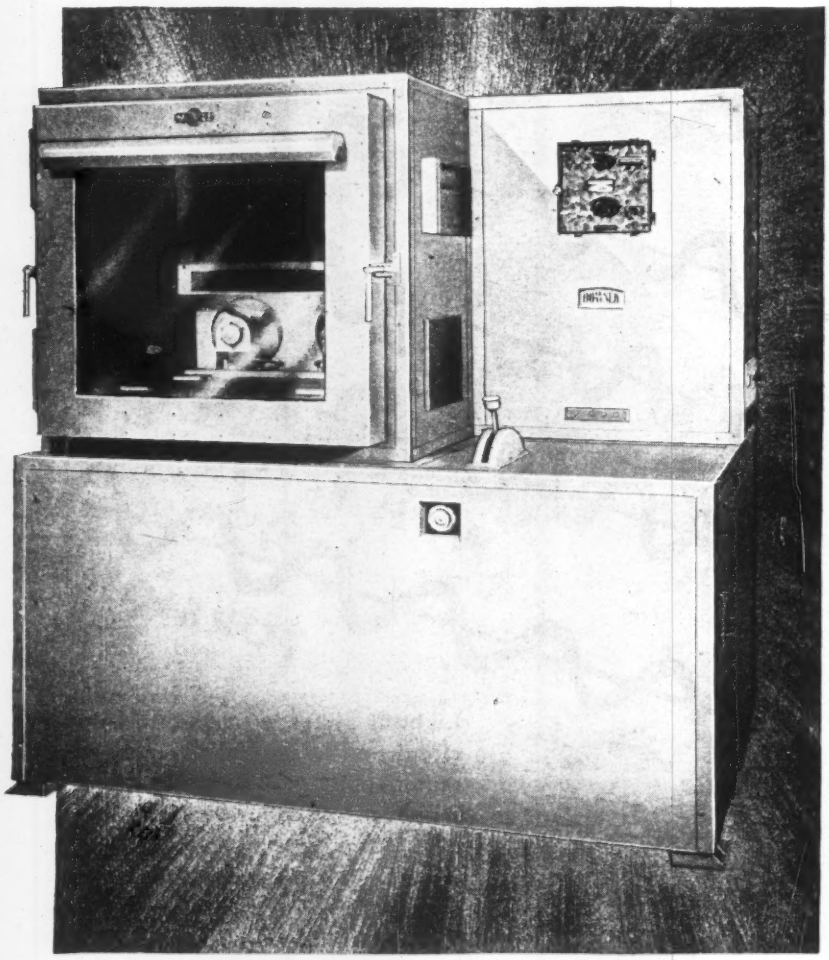
Lower THAN A SUB CAN SUBMERGE

The high-to-low instrument testing range of Bowser-built Testing Chambers is considerably greater than can be obtained with the highest practical actual flight plus the greatest submerging depth. This permits a tested and proved safety factor—a priceless asset.

That's one big reason why instrument makers are turning more and more to Bowser-built Test and Calibration Chambers, which have demonstrated their efficiency and practicality time after time in actual operation.

There are other big reasons, too. For instance, chamber testing is much less costly—no expensive personnel, motor fuel, etc. In fact, a Bowser Chamber costs probably less than testing a bomber one hour under actual flight conditions. Moreover, chamber testing is much quicker and immeasurably safer.

Aggressive manufacturers are installing testing chambers . . . not relying on laboratories already burdened with research work. Write for complete information or, better still, our engineers will gladly consult with you.



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Mobile Refrigeration Division

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BOWSER ESTABLISHED 1885

Not only has Bowser's war production earned the Army-Navy E . . . Bowser equipment has helped earn it for scores of other companies.

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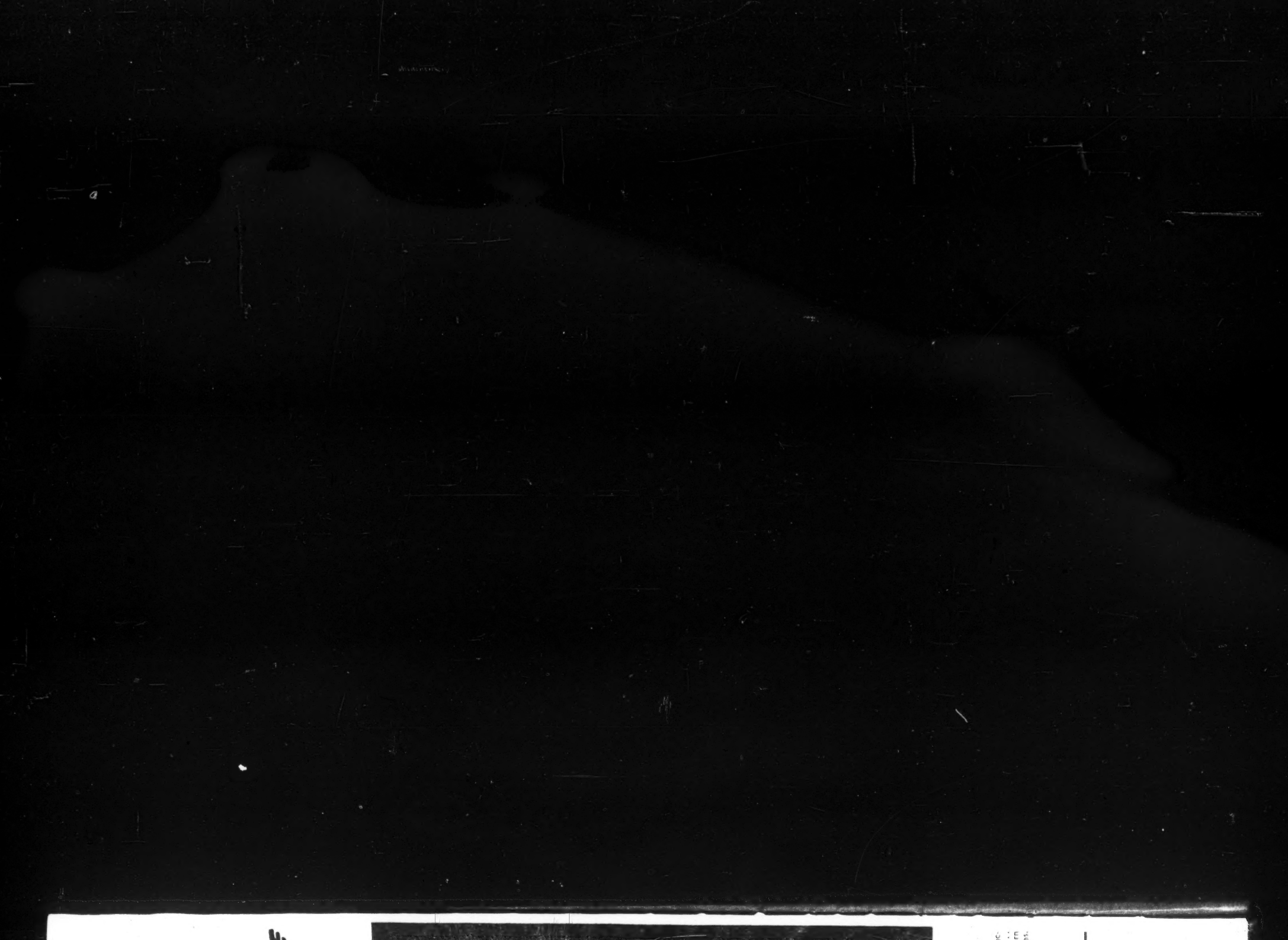
THE NAME THAT MEANS **EXACT CONTROL** OF LIQUIDS



DAVEN

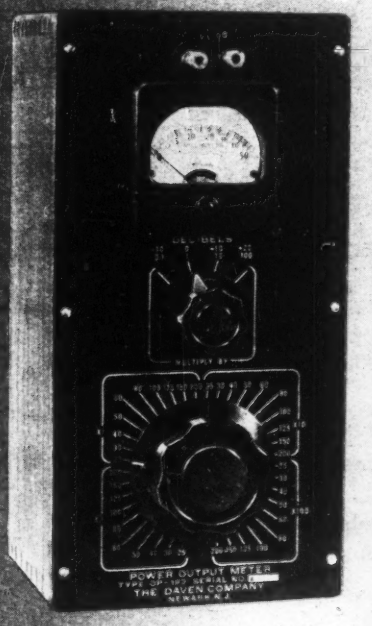
POWER OUTPUT METERS

DESIGNED TO MEASURE POWER OUTPUT

- at fixed impedance and fixed frequency
- at fixed frequency and variable load
- at fixed load and variable frequency

ALSO

- to determine internal impedance or optimum load
- to measure insertion loss of a network
- to measure noise pick-up level
- to test band width, selectivity, fidelity, sensitivity



OP-182

Power Range: 0.1mw to 5 watts.
Impedance: 40 values, 2.5 to 20,000 Ω
Accuracy: ±5%.

OP-193-A — OP-193-B

Power range: 0.1mw to 5 watts.
Impedance:
OP-193-A—18 values, 400 to 30,000 Ω
OP-193-B—40 values, 2.5 to 20,000 Ω
Accuracy: ±5%.
Special Feature: Provision for use of headphone and ac meter.

The DAVEN OP Series Power Output Meters offer a selection of four models for measuring the effect of power and load on audio amplifiers, filters, oscillators and similar equipment, as well as for standard radio receiver tests. Types OP-182 and OP-961 are widely accepted for their wide flexibility, accuracy and durability. Types OP-193-A and OP-193-B are especially adapted for noise pick-up level work in testing radio receivers, where the use of headphones is desired. A special three-position switch enables use of headphones circuit, meter circuit or both simultaneously.

OTHER SPECIFICATIONS

INDICATING METER

Rectifier type AC, calibrated 1 to 50mw and 0 to 17 DB. Reference level 0 DB = 1mw.

METER MULTIPLIER

OP-182, OP-193-A, OP-193-B—Extends meter power reading, 0.1 to 100 X scale; DB reading, —10 to +20 DB, in 10 DB steps.

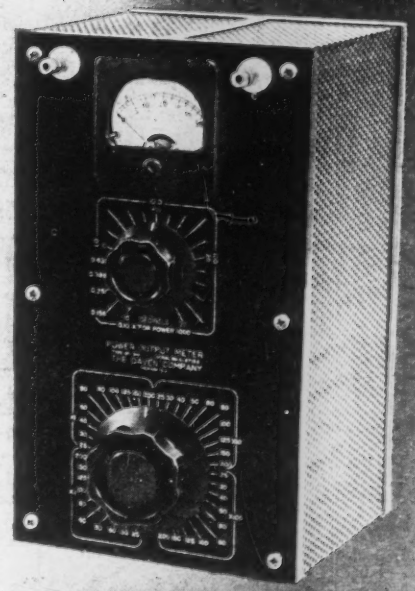
OP-961 — Extends meter power reading, 0.1 to 1000 X scale; DB reading, —10 to +30 DB, in 2 DB steps.

MOUNTING

OP-182 — Black metal panel, hand rubbed walnut cabinet, 12"x6"x6"

OP-961—Black metal panel, ventilated metal case, 12"x7"x6½".

OP-193-A, OP-193-B — Black bakelite panel, portable cabinet with removable cover, 13¾"x7¾"x5¼".



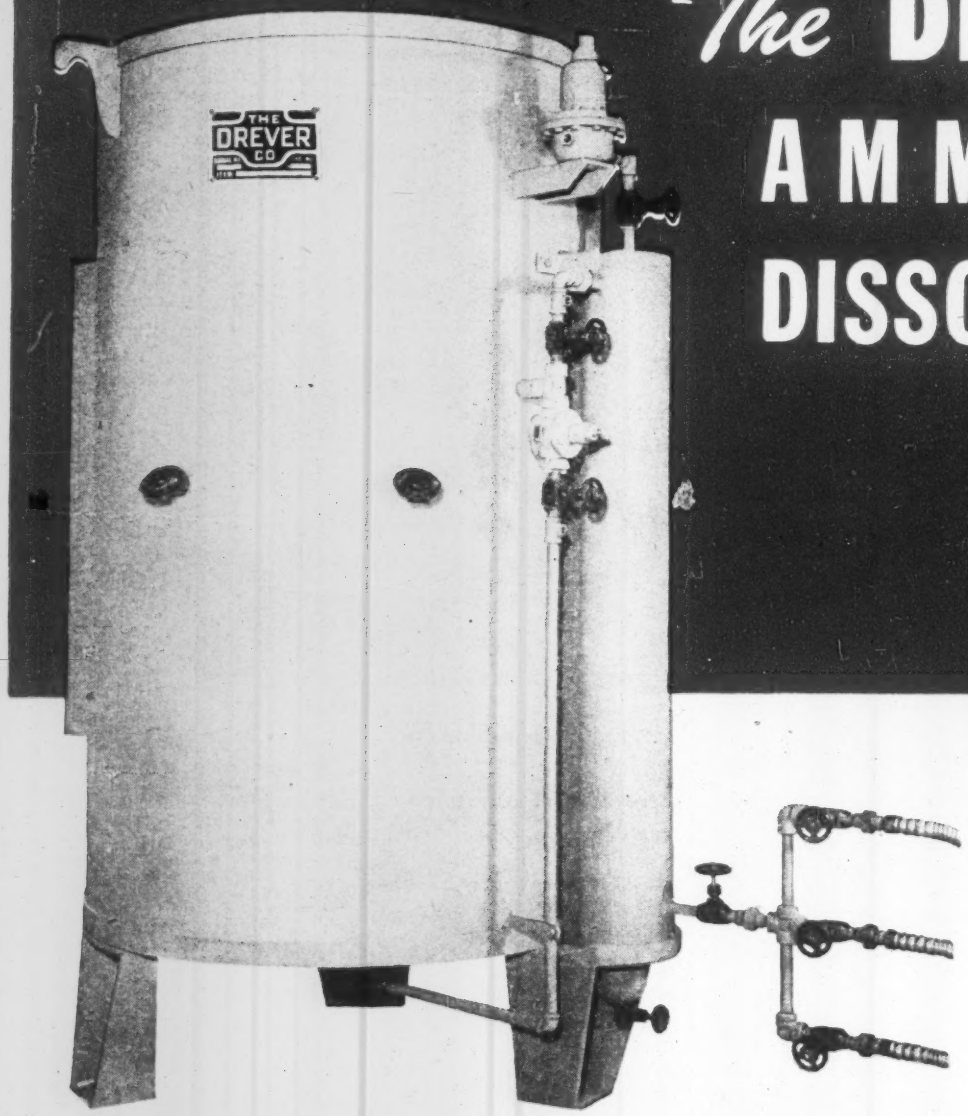
OP-961

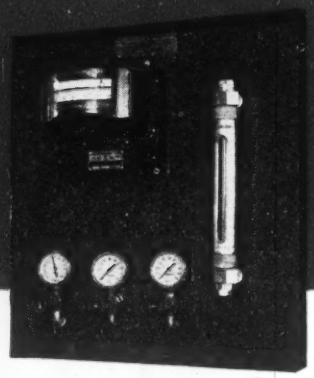
Power Range: 0.1 to 50 watts.
Impedance: 40 values, 2.5 to 20,000 Ω
Accuracy: ±2%.

BUY, HOLD, GIVE—WAR BONDS!

THE DAVEN COMPANY
191 CENTRAL AVENUE
NEWARK 4, NEW JERSEY

The DREVER AMMONIA DISSOCIATOR





TYPICAL CONTROL PANEL

The cost of bottled ammonia is approximately one-third that of bottled hydrogen. One 100 lb. cylinder of ammonia produces the equivalent of seventeen-200 cubic foot cylinders of hydrogen. Obvious savings in cost, storage and handling.

A COMPLETE RANGE OF SIZES FOR EVERY REQUIREMENT

SIZE	KW
100 CFH	3½
250 CFH	7
500 CFH	12
1000 CFH	20
2000 CFH	40

Laboratory sizes not listed above are available for use in experimental and developmental work.

The Drever Ammonia Dissociator produces the ideal economical furnace atmosphere for:

1. ***Bright Annealing*** stainless steels, beryllium copper, pure nickel and nickel alloys, silicon steels, and other difficult and exacting metals
2. ***Hydrogen Brazing***
3. ***Bright Hardening*** of high chrome steels
4. Reduction of metallic oxides and sintering of powdered metals
5. ***Atomic Welding***

The inherent quality and economy of these units is being proved in service in many plants all over the country. Deliveries are good. For complete details write:

THE DREVER CO.

782 E. VENANGO STREET, PHILA. 34, PA.

New York and New England — Gerald B. Duff, 68 Clinton Ave., Newark 5, N. J.

PRESSURE QUENCHES · CONTINUOUS FURNACE LINES · HEAT TREATING FURNACES

Provide Dependable Power

and Meet

Mechanical Design Specifications

Holtzer-Cabot Powered Tabulating Machine

The problem of a well-known manufacturer of business machines was to obtain a motor and a generator that not only provided the correct power to operate extremely sensitive solenoids but also fit the space which was at a premium. Holtzer-Cabot motor development engineers tackled the job and designed a special motor and generator with the proper performance characteristics in special frames which fitted the space specifications . . . and another motor problem was solved.

For over 50 years Holtzer-Cabot has concentrated its energies in designing and building special motors.

And although today, our plant facilities are devoted entirely to manufacturing special fractional H. P. motors for war products, our development engineers will gladly cooperate with you on your post-war fractional H. P. motor requirements

Special Motors Designed to Fit the Application

HOLTZER-CABOT

Division of First Industrial Corporation

Designers and Builders of Special Fractional HP Motors and Electrical Apparatus

125 AMORY STREET, BOSTON 19, MASSACHUSETTS • CHICAGO, ILL. • NEW YORK, N. Y. • PHILADELPHIA, PENNSYLVANIA

RAYTHEON VOLTAGE STABILIZERS

CONTROL VARYING LINE VOLTAGES

TO 115 VOLTS ± ½%

Ordinary A.C. line voltages as taken from supply mains often vary as much as from 95 to 130 volts. This impairs the precision operation of electrical equipment.

A Raytheon Voltage Stabilizer, built into new products or incorporated into equipment already in use, overcomes the disadvantage of fluctuating voltages by providing an accurately controlled source of power to ± ½%.

Here's what a Raytheon Stabilizer does—stabilizes varying input voltage from 95 to 130 volts to 115 volts ± ½% within 2 cycles.

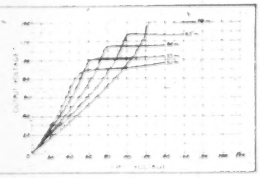
Raytheon Voltage Stabilizers are entirely automatic. They require no adjustments or repeated maintenance. No moving parts assure long life. Write for bulletin DL 48-537.

EFFECT OF VARIABLE FREQUENCY

Since partial resonance is a requisite design feature, these devices are sensitive to frequency changes. The output voltage will vary in the same direction and 1.4 times the percentage change in frequency, over a range of 5% of the normal frequency.

Stabilization, however, will be within ± ½% at the output voltage which is established by the frequency.

TYPE VR 2
INPUT VS OUTPUT VOLTAGE
FOR VARIOUS FREQUENCIES



Tune in the Raytheon radio program: "MEET YOUR NAVY," every Saturday night on the Blue Network. Consult your local newspaper for time and station

RAYTHEON
MANUFACTURING COMPANY
Electrical Equipment Division
190 WILLOW STREET, WALTHAM, MASS.

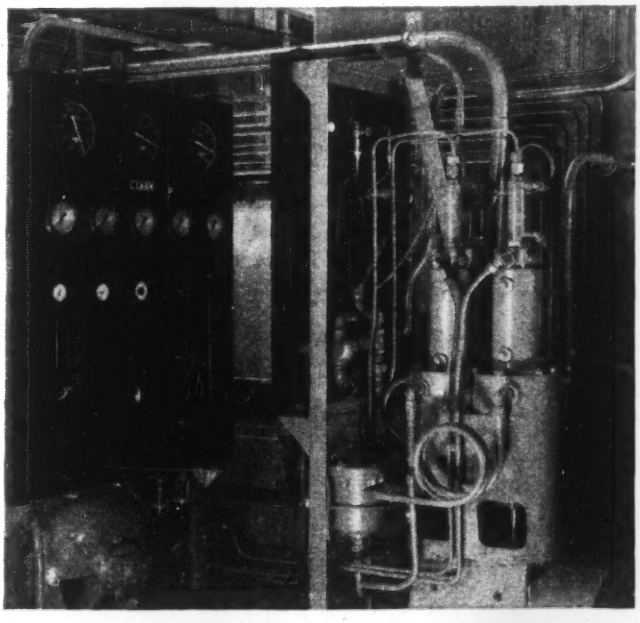
The coveted Army-Navy "E," for Excellence in the manufacture of war equipment and tubes, flies over all four Raytheon Plants where over 16,000 men and women are producing for VICTORY.

Devoted to research and manufacture of complete electronic equipment; receiving, transmitting and hearing aid tubes; transformers; and voltage stabilizers.

How cold is 320° below?

WHAT'S it like at —320°F? And how do you measure it *accurately* under severe field conditions?

This was a question that had never come up until we were handed a neat little problem by Clark Bros. Co. and the M. W. Kellogg Co. in connection with a highly important piece of U. S. Army equipment, the purpose of which cannot be disclosed. It was an interesting challenge. Nevertheless, our long experience in designing tube systems to meet the unusual demands of industry permitted us to take the job in our stride. To be sure, it took some "doing" to provide the necessary over-range protection to withstand atmospheric temperatures as high as 150°F. when not in service; to produce the calibrating equipment; and to determine which metals would perform safely when exposed to such low temperatures.



Not all of our work is this spectacular. But the point we wish to make is that this particular job is another interesting, and entirely practical, application of tube system type instruments, and the versatility of Taylor Engineers.

Whether *you* want to plumb the depths of unexplored low temperatures—or measure or control any temperatures from there on up to 1000°F.—you can depend on Taylor capillary type thermal elements. Taylor Instrument Companies, Rochester, N. Y., and Toronto, Canada. *Instruments for indicating, recording and controlling temperature, pressure, humidity, flow and liquid level.*

ARMY (E) NAVY

Taylor Instruments
MEAN
ACCURACY FIRST
IN HOME AND INDUSTRY

BUY MORE WAR BONDS — AND KEEP 'EM

Photo courtesy of Addressograph-Multigraph Corporation

High Priorities...

BOUGHT THIS BRUSH SURFACE ANALYZER

When the Addressograph-Multigraph Corporation in Cleveland, found it necessary to accurately measure the surface finish on grained zinc plates, they bought a Brush Surface Analyzer to do the job. Now, they are able to control these surfaces to micro-inch roughness by studying graphic readings of the irregularities measured to one millionth of an inch (.000001").

This instrument was purchased with a high priority rating. No longer is this necessary. Greatly expanded production facilities are now enabling us to make *prompt delivery* with *no priorities.*

The Brush Surface Analyzer is an indispensable tool in modern production where closer control of surface finish is greatly emphasized.

See how this instrument can best serve your production needs by a demonstration at your plant.

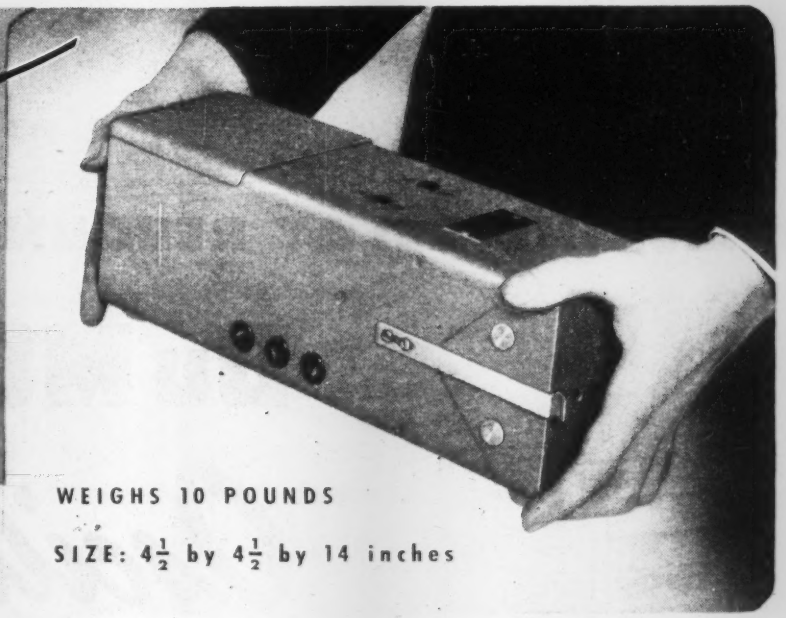
Also write for a free brochure—"Surface Finish—.000001 inch."

THE BRUSH DEVELOPMENT COMPANY

3413 PERKINS AVENUE • CLEVELAND 14, OHIO

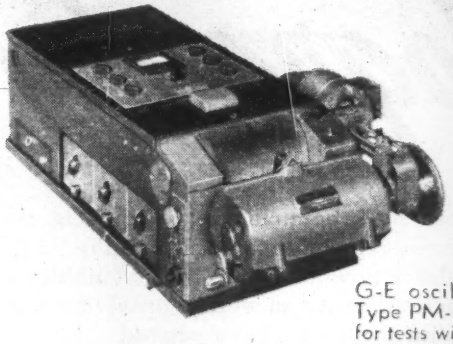
Announcing

A MINIATURE OSCILLOGRAPH



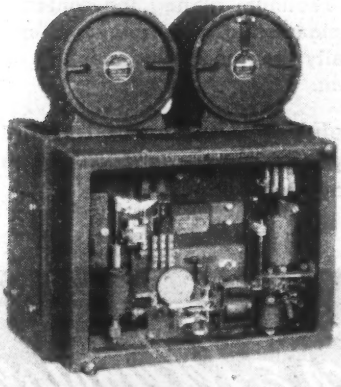
WEIGHS 10 POUNDS

SIZE: 4½ by 4½ by 14 inches



G-E oscillograph, Type PM-10, set up for tests with magazine film holder, driving head, and a-c motor unit

Portable oscillograph, Type PM-12, for general use where only two elements are required



Automatic oscillograph, Type PM-13. Starts recording one-quarter cycle after disturbance occurs

THIS 6-ELEMENT OSCILLOGRAPH was developed for use where light weight and small size are essential. It's easily portable, to obtain "on the spot" photographic records of the characteristics or the performance of many machines and devices. Records simultaneous variations of six rapidly changing phenomena. Type PM-17; net price, $850 up. Write today for leaflet GEA-4331.

IF SMALL SIZE IS NOT ESSENTIAL, HERE ARE OTHER G-E OSCILLOGRAPHS

TYPE PM-10—Records 6 to 12 phenomena simultaneously. A large, multi-element, general-purpose oscillograph for a wide field of application. Includes simultaneous viewing with recording. Net price, $3160 up.

TYPE PM-12—Anyone can operate it. For work in the field, in the laboratory, or in the classroom. For either visual indications or taking oscillograms of current and voltage waves. Originally developed for school use, industry has found this 2-element portable especially valuable for observing or recording welding current. Net price, $665.

TYPE PM-13—Entirely automatic. Can take as many as 100 oscillograms of transients and surges without attention. Particularly useful for determining the sequence of relay and breaker operation and the effect on system stability. Net price, $2125.

Our nearest office will be glad to help you select the right oscillograph for your specific requirements. *General Electric Company, Schenectady 5, N. Y.*

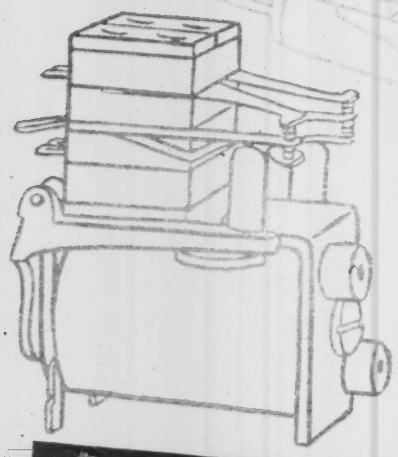
BUY WAR BONDS AND KEEP THEM

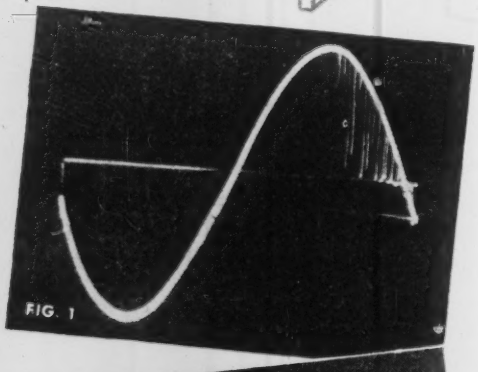
GENERAL ELECTRIC

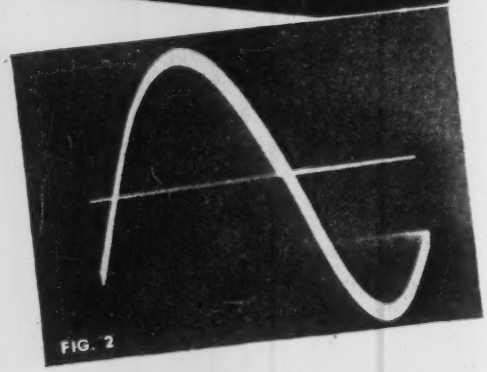
CHECKING RELAY REBOUNCE BY MEANS OF

DuMONT

Oscillography







Parasitic oscillations caused by rebouncing relay contacts can prove mighty troublesome. However, *DuMont Oscillography* (oscillographic equipment plus the know-how) can be invaluable in determining the source of such difficulty as well as providing conclusive evidence that remedial measures have proved effective. For instance:

A standard DuMont oscillograph with single-sweep feature is used. No additional accessories required. Relay is actuated by closing a switch. Relay contact applies 60-cycle wave to vertical deflection plates of cathode-ray tube. With sweep frequency set at 60 cycles, one complete sine wave period appears on screen.

If relay contact closes without rebounce, the transition from horizontal line to sine wave is a simple straight line and generally occurs so quickly that it is difficult to observe visually. However, if rebounce is present, the interruptions are indicated by a series of parallel vertical lines readily observed, as in Fig. 1.

If it is desired to determine the number of interruptions and duration of rebounce periods, photographic records are made. Since the frequency of the sine wave is known, the evaluation of results is simple. In this oscillogram there were over 20 rebounces before establishing definite contact. Total duration of series of rebounces is 1/250th second. Time between opening and closing of contact is about 50 microseconds. Greater accuracy may be had by using higher frequency wave generated by an external oscillator.

Fig. 2 oscillogram demonstrates that rebounce has been eliminated by cadmium plating the contacts, amalgamating with mercury, and finally dropping liquid mercury on them.

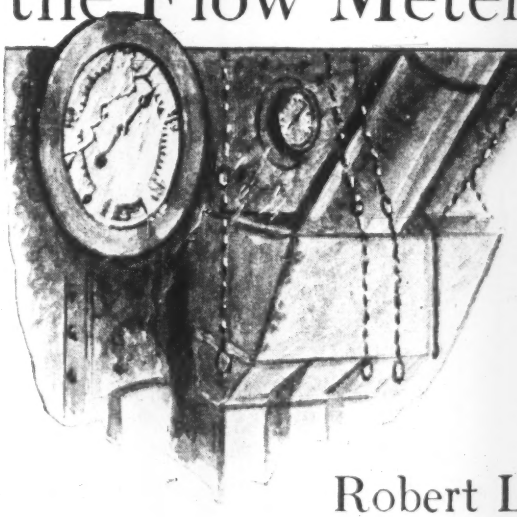
An illustration from hundreds of useful applications of DuMont Cathode-Ray Oscillographs. Perhaps your measurement technique can be simplified or improved upon by DuMont.

© ALLEN B. DUMONT LABORATORIES, INC.

DUMONT *Precision Electronics & Television*

ALLEN B. DUMONT LABORATORIES, INC., PASSAIC, NEW JERSEY • CABLE ADDRESS: WESPEXLIN, NEW YORK

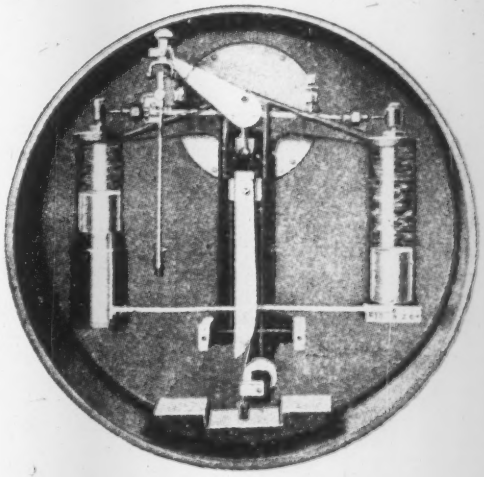
The Story of the Dirty Boiler Room and the Flow Meter with the Cracked Glass



This one belongs in the famous "Believe It or Not" series of Robert L. Ripley:

A Cochrane Flow Meter, of the tilting U-tube type, was installed in a boiler room, which, far from being the bright, clean, "eat-off-the-floor" variety the readers of this magazine are familiar with, was very dirty indeed. The operators, again unlike our readers, were probably rather careless, for the glass on the meter door was cracked and no one bothered to replace it. The meter, being of the indicating type, required no change of chart, or other excuse for opening the door, but continued to function properly for two years. Then there was an inspection, and it was found that the meter case was half-filled with coal dust... and that the tilting manometer had kept ploughing a clear path for its operation. Its accurate performance had not been affected. That's POWER!

What is the secret of this power inherent in every Cochrane Tilting U-tube type of Flow Meter?



Simply this: the difference in rate of flow in the pipe line changes the level of the mercury in a sealed U-tube which is balanced on a knife-edge bearing. As the mercury shifts from one side to the other of the U-tube, the balance swings, moving indicator, pen arm and integrator to record the change in flow.

Simple . . . powerful . . . never-failing. If you have a tough metering job, if your operators are unskilled in instrument care and maintenance, if you want the simplest and most powerful flow meter made, this Cochrane Tilting U-tube Meter was made for you. Write today to Cochrane Corporation, Flow Meter Division, 3120 N. 17 St., Philadelphia 32, Pa.

A NEW -*hp*- AUDIO OSCILLATOR

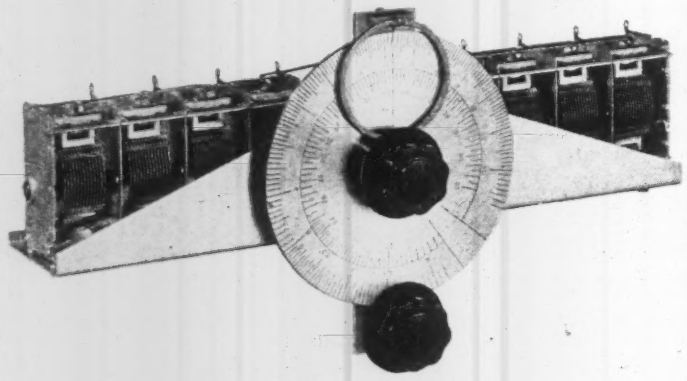
3 OUTSTANDING NEW FEATURES:

1. ACCURATE CONTROL DIAL

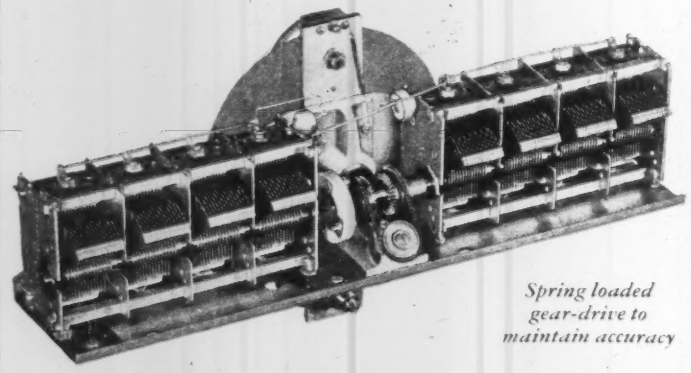
EASY TO READ • NO PARALLAX

2. RUGGED CONSTRUCTION

3. IMPROVED CIRCUIT

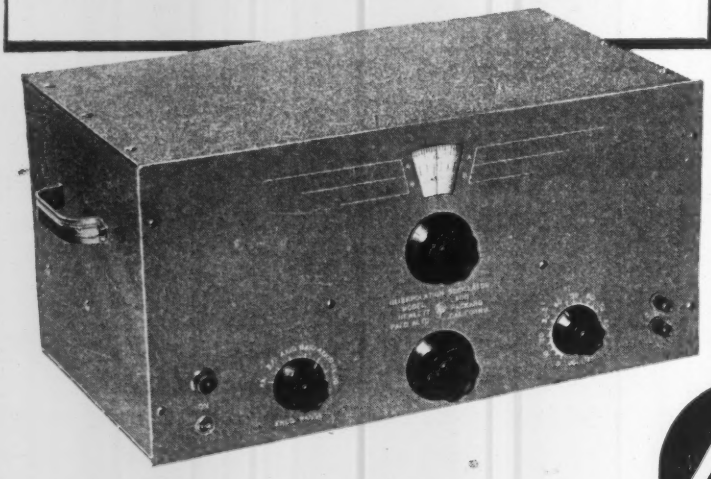


New friction driven dial provides hair-line accuracy



Spring loaded gear-drive to maintain accuracy

Rugged chassis construction on heavy cast frame



The Model 200-I is a resistance-tuned audio oscillator designed to provide high stability and accuracy for use in frequency measurements. It has a range from 6 cps to 6000 cps,* divided into six frequency ranges as follows: 6 to 20, 20 to 60, 60 to 200, 200 to 600, 600 to 2000 and 2000 to 6000 cps. Each of these ranges has an individual frequency adjustment so that the instrument may be set to a frequency standard such as the -*hp*- Model 100-B.

The large, 6-inch diameter, main frequency dial is calibrated over approximately 300 degrees, making possible a large number of calibrated points to cover the entire range. The dial itself rotates behind a fine wire locator which is visible through an opening in the panel. Parallax is completely eliminated and calibrations are spread over an effective scale length of nearly eight feet. Fast and extremely accurate settings are made easily with this dial. There are two manual controls: one direct action, and the second for vernier adjustments. An electronically regulated power supply is included to assure greatly improved stability.

The Model 200-I -*hp*- Audio Oscillator is but one among many new -*hp*- instruments which are to make public appearance as the cloak of military secrecy is removed. Preliminary technical information is available on this instrument now . . . write for it! And watch for the early release of other new -*hp*- instruments.

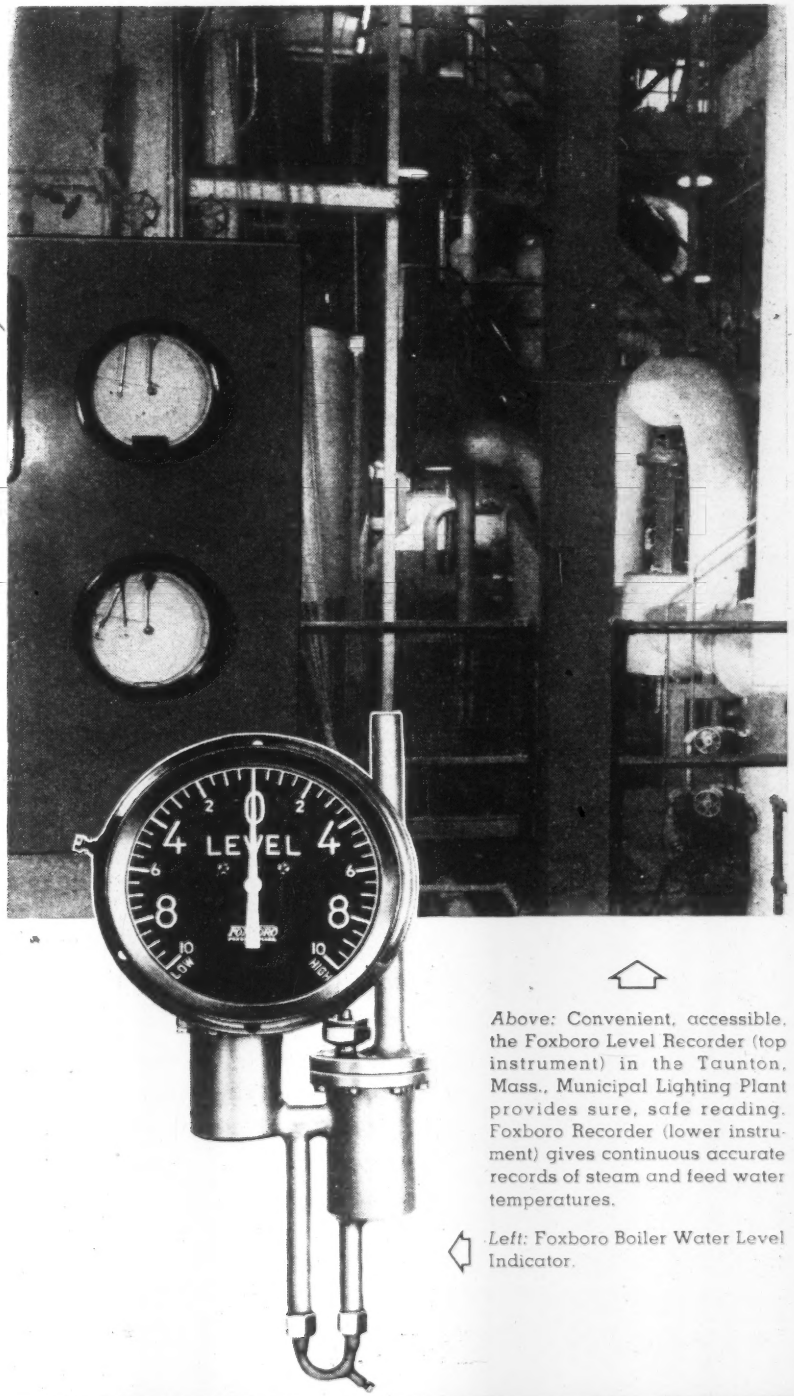
**This frequency coverage was selected for interpolation work. Other frequency ranges can be supplied from 6 cps to 100 kc on special order.*

HEWLETT-PACKARD COMPANY

P. O. Box 930 C Station A, Palo Alto, California

930

They Even Prevent Human Forgetfulness!



Above: Convenient, accessible, the Foxboro Level Recorder (top instrument) in the Taunton, Mass., Municipal Lighting Plant provides sure, safe reading. Foxboro Recorder (lower instrument) gives continuous accurate records of steam and feed water temperatures.

Left: Foxboro Boiler Water Level Indicator.

Foxboro Liquid Level Indicators and Recorders bring boiler-water readings out where they practically can't be overlooked!

Here's a typical example of the engineering thoroughness that goes into the design of every type of Foxboro Instrumentation.

Even the hazards of human carelessness in boiler operation have been foreseen in the design of Foxboro Boiler Water Level Instruments. These safer level gauges are designed for mounting at eye-level in the most-accessible location . . . *where frequent reading practically can't be overlooked!*

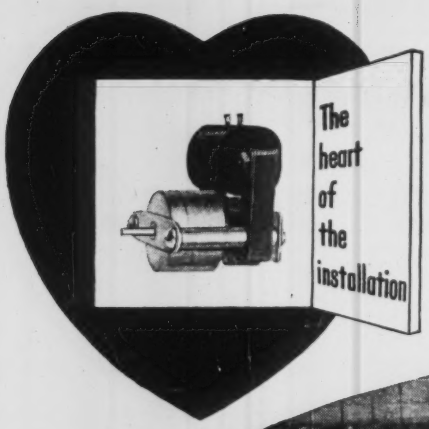
What's more, the Indicator has a highly visible dial that shows up clearly in any light where men can work. The Recorder not only permits easy check-up at any instant, but provides continuous graphic records to *prove* whether correct level has been maintained.

Foxboro Boiler Water Level Indicators and Recorders are made for any pressures encountered in modern steam power plant practice. Simply, ruggedly constructed to serve many years without maintenance. No glass to break . . . easily installed without disturbing the gauge-glass. Write for detailed information. **The Foxboro Company, 46 Neponset Avenue, Foxboro, Mass., U. S. A.**

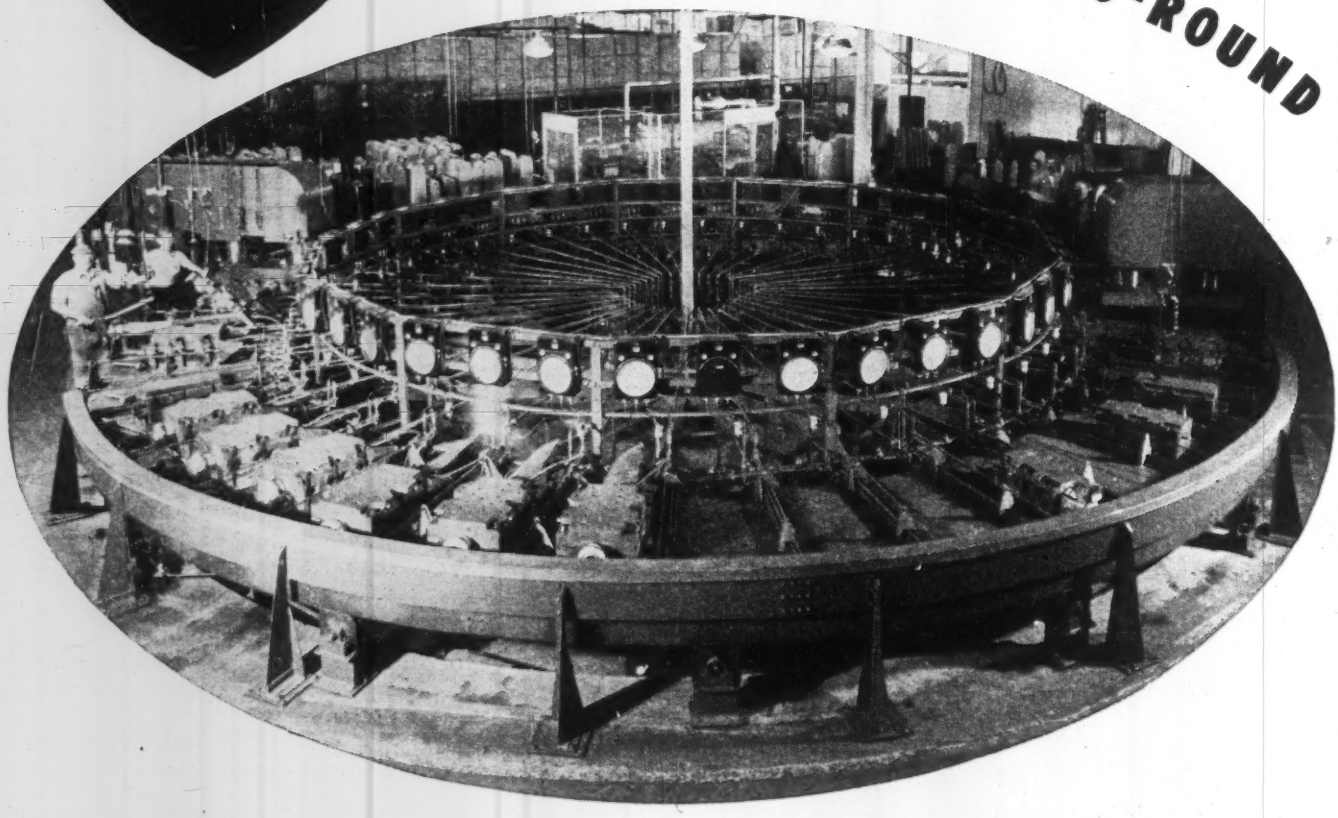
ATLANTA, GA., Room 713, 101 Marietta Street Bldg.

FOXBORO
REG. U. S. PAT. OFF.

BOILER WATER LEVEL INSTRUMENTS



TELECHRON SETS THE PACE FOR THIS MERRY-GO-ROUND



This 100-ton "merry-go-round" curing press for fairings or "cuffs" on propeller blades was built in an Eastern plant to break a bottleneck in the production of these critical airplane parts.

Ebonite fairings on two sets of 21 propeller blades are cured simultaneously under the direction of the 42 instruments mounted around the center — one for each curing mold. And these instruments are driven by synchronous, self-starting Telechron motors. They control temperatures in the curing mold through cam-operated water and steam valves, and provide records of curing time and pressure for each blade being processed.

Adaptable and dependable, Telechron motors are doing all kinds of timing, controlling and recording jobs in many different fields — helping to break bottlenecks and speed victory. They are available in sizes from 12 to 250 volts for all commercial frequencies — and from 1 to 1800 rpm. Their industrial applications include:

TIMING • CONTROLLING • METERING • RECORDING
SWITCHING • CYCLING OPERATIONS • SIGNALING
FIXED PROCESS CONTROLLING • MEASURING • GAGING
REGULATION • COMMUNICATION

Our experience as the oldest and largest makers of synchronous, self-starting electric motors for instrumentation is freely available to you. If you'd like our help, just write Motor Advisory Service, Dept. B.

Telechron
REG. U. S. PAT. OFF.
WARREN TELECHRON COMPANY
ASHLAND MASSACHUSETTS

MAKERS OF TELECHRON ELECTRIC CLOCKS AND SYNCHRONOUS ELECTRIC MOTORS

PRECISION ELECTRICAL MEASURING INSTRUMENTS

by ROLLER-SMITH

MINIATURE PANEL AND SWITCHBOARD INSTRUMENTS

Sturdy construction contributes to the permanent accuracy of these precision electrical instruments. Size ranges from small light-weight units to large instruments for power plant switchboards. 3.5" Type T. Scale length 2.1". Accuracy 2%. Available in square or round, flush or projection models for measuring d-c microamperes, milliamperes, amperes, volts and millivolts; a-c microamperes, milliamperes, amperes and volts. Supplied in all popular ranges.

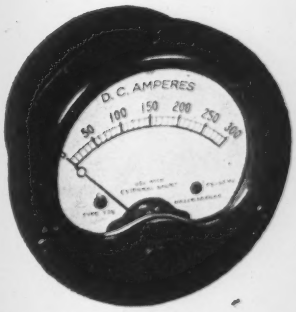
4" Type F in round, flush or projection case. Scale length 2¾" for round models and 3⅝" for square models. Accuracy 1%.

4½" Type FJ in semi-flush rectangular case. Scale length 3⅞" for d-c, 3⅝" for a-c. Accuracy 2%.

Both 4" and 4½" models are available for measuring d-c microamperes, milliamperes, amperes, volts and millivolts; a-c microamperes, milliamperes, amperes and volts in all popular ranges.

1½" d-c ammeters and voltmeters, aircraft type. Design and development of these instruments were based on U. S. Army Air Corps specifications. Ammeters are available in all practical ranges above 500 microamperes; voltmeters in all practical ranges above 50 millivolts.

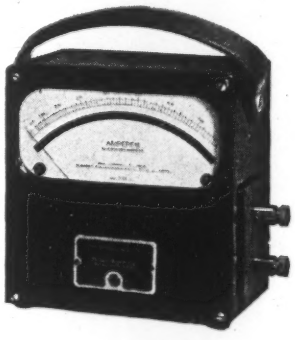
2½" a-c voltmeters, range and scale 0-150 volts, 400 cycles. These instruments are built for special aircraft use and are designed to meet the most rigid aircraft specifications.



3.5" Round Flush Bakelite Case Miniature Panel Instrument

4.5" Semi-flush Bakelite Case Panel Instrument

PORTABLE INSTRUMENTS



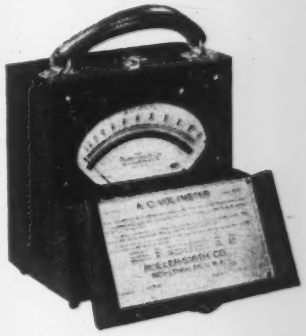
Type "Steel-Six" Portable Instrument

Combining high accuracy with dependability, Roller-Smith portable instruments are ruggedly built for severe service.

"Steel-Six"—Size 6" x 6" x 4". Scale length 5⅜". Accuracy ½ of 1% for d-c instruments. For a-c ammeters, voltmeters and single phase watt meters, ½ of 1%; 1% for polyphase watt meters, frequency meters and power factor meters. Designed for general testing where an accurate but moderately priced instrument is required.

Type NP—Size 8" x 8" x 5½". Scale length 5¼". Accuracy ⅓ of 1%. Designed for general testing where a highly accurate and extremely rugged instrument is required. Units measured are d-c amperes, milliamperes, volts and millivolts; a-c amperes, volts, watts, power factor and frequency. All popular ranges are available in single or multi-range models.

Send for literature



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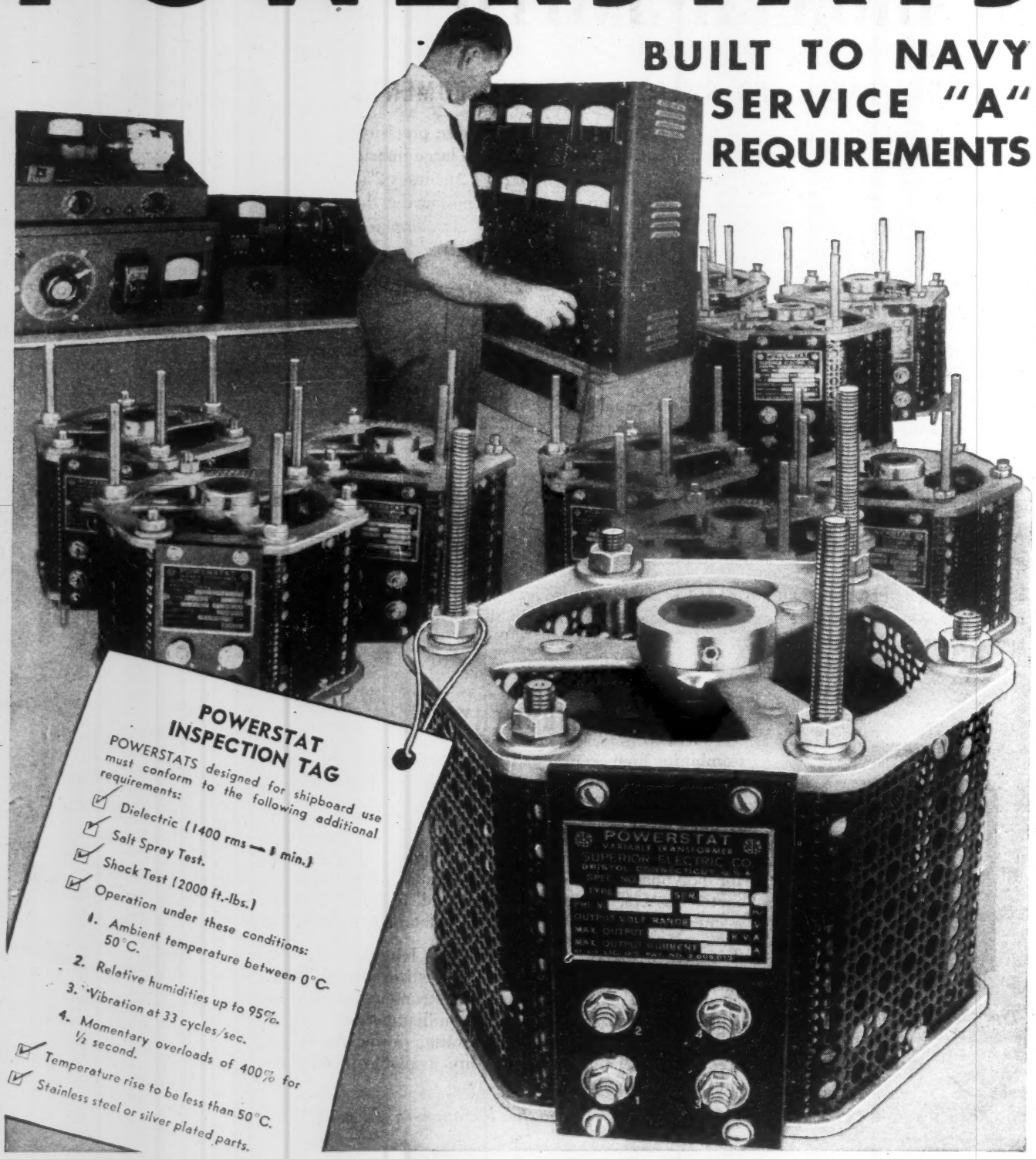
POWERSTATS

BUILT TO NAVY SERVICE "A" REQUIREMENTS



POWERSTAT INSPECTION TAG

POWERSTATS designed for shipboard use must conform to the following additional requirements:

- ☑ Dielectric (1400 rms — 1 min.)
- ☑ Salt Spray Test.
- ☑ Shock Test (2000 ft.-lbs.)
- ☑ Operation under these conditions:
  1. Ambient temperature between 0°C. 50°C.
  2. Relative humidities up to 95%.
  3. Vibration at 33 cycles/sec.
  4. Momentary overloads of 400% for ½ second.
- ☑ Temperature rise to be less than 50°C.
- ☑ Stainless steel or silver plated parts.

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SUPERIOR ELECTRIC COMPANY

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Revolutionary in Range!

CML MODEL 1200

STROBOSCOPE

"FREEZES" MOTION IN RANGE OF 600 TO 600,000 RPM

Rotary speeds from 600 to 600,000 RPM—or vibrations from 10 to 10,000 CPS—can be "stopped" and studied with the Model 1200 Stroboscope. The light source is mounted in a small probe at the end of a five-foot flexible cable.

This makes it easy to examine small objects at close range. Provision is made to operate the unit from external tuning fork or crystal standards, where extreme accuracy is required. The motion of objects moving at irregular speeds may also be "stopped" with the Model 1200.

An accurate repetitive pulse rate is obtained as the pulses are derived from a stable audio oscillator.

Not only does this eliminate the necessity for constant readjustment of the repetitive rate, but it also insures clearly defined images at high speeds.

For greater flexibility, a light intensity control switch is also provided. This enables the user to control both the intensity of the light and the duration of the pulse length.

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DIRECTIONS FOR USE OF FAXFILM

(Trade Mark Reg. U. S. Pat. Off.)

An Economical — Speedy — Simple Method of Surface Inspection — Surface Contours Enlarged 100 Diameters in Three Dimensions.

Faxfilm method reproduces surface finishes of any material in THIRD DIMENSION for instant comparison with standards for roughness, waviness and lay, and for checking surfaces for cleaveage, cracks, porosity, dents, scratches, etc., by means of projection on any projector. Enlarged 10,000 times, or 100 diameters, Faxfilm is distinct and will show details of the finest irregularities up to .0001".

Faxfilm is non-inflammable and can be used with high powered projectors, and will withstand high heat without distortion.

At a small fraction of the cost of a photomicrograph, a complete Faxfilm three dimensional replica is made in less than a minute by a few simple operations.

Here's How You Do It

1. Cut off 1 inch of film with scissors.
2. Wet surface specimen with solvent—about 2 drops is all that is necessary.
3. Press film firmly on surface.
4. Let dry for 30 to 60 seconds.
5. Using moistener supplied in Kit, moisten entire gummed surface of frame so that adhesive will be softened to hold film when ready.
6. Peel Faxfilm from specimen.
7. Affix in gummed Faxfilm frame for projection.

The record of your specimen surface is now permanent and unalterable.

Caution

It is very essential that the entire gummed surface of the Faxfilm frame be wet before mounting the film, otherwise the frame is liable to open up.

Be sure solvent does not get on the upperside of the film as it will mold a fingerprint on the film when pressed down on the surface. If there is any danger of getting solvent on the fingers, a few drops of olive oil on fingertips will avoid fingerprints on reverse side of film when it is rubbed down on surface specimen.

If surface is dirty, it may be cleaned with the solvent by brushing. Care must be taken in using a cloth that lint is not left to become attached to the replica. Very often Faxfilm is used to determine the amount of corrosion on the specimen, and when using it for this purpose, the surface is not cleaned. Much of the corrosion will be attached to the film and will show as opaque particles when projected.

When making experiments on anything to which the dissolved plastic might adhere, it is necessary to first oil the surface, preferably with a little olive oil or light oil such as Three in One. The oil should be dropped on the surface and rubbed in, then when the Faxfilm is made, the solvent should be applied to the film by brushing and then rubbed down. Do not let this type of replica remain on longer than one minute, otherwise it is liable to pull up fibrous material into the film.

Film should be held firmly on surface and not allowed to slide or replica will be smeared.

Let the film set for 40 seconds or up to 15 minutes after applying to surface. If too short a time is allowed, the replica is marred and not true. If allowed to dry too long, the Faxfilm is liable to take a permanent curl set.

Peel the film from the surface specimen starting at the end, not from the side.

Mount film in Faxfilm Frame immediately after peeling from surface to avoid film curl.

If clear spots appear in the film, it indicates that air bubbles are present and that the Faxfilm has not been pressed down firmly enough on the surface to remove them or that insufficient solvent has been used.

In comparing micro finished surfaces, the highest enlargement possible should be used.

Faxfilm reproductions of etched metal require a firm pressure and are more distinct on etched material than the plain ones.

When working on curved surfaces, such as the side of a cone, a more uniform impression is obtained by using the shortest possible length of film.

Faxfilm may be tinted by means of eosine, methylene blue, or other dyes, and in some instances are helpful in bringing out contrasts.

It is often useful to calibrate a screen by laying it off into divisions of one inch and 1/10th of an inch, where the 100 diameter enlargement equals 1/100th of an inch and 1/1000 of an inch over the enlarged Faxfilm picture. Many specimens are apparently out of focus for the entire film, but by moving the focus back and forth, different planes may be inspected and a calibration on the focusing lens will determine definitely the distance between planes.

Replicas of fine botanical and zoological specimens may be made by oiling the specimen and pressing down firmly into the film on which solvent has been applied. Great care must be taken that the solvent does not get on the other side of the film.

Faxfilm is used in crystallography in examining various salts. The salts is sifted one layer thick on a clean surface. The Faxfilm is treated with the solvent and held in both hands and touched down on the surface to pick up the crystals. It is then immediately mounted in the Faxfilm frame before drying and is ready for projection. Polaroid may be used to polarize the light used for crystal examination.

Faxfilm **cannot be made** on surfaces that are soluble in the solvent such as painted and lacquered surfaces.

Faxfilm Model B-500 Micro-Projector with 1" focal length lens and all materials required to make 500 Faxfilm Lantern Slides.... **$72.50**

If projector is not required order **Faxfilm Model A-250** Kit with all materials and equipment required to make 250 Faxfilm Lantern Slides. Prompt Shipment **$15.00**

Ready January 15—**Faxfilm Dual Comparator**—an ideal apparatus for the shop and laboratory to study and control surface finishes. Write for details. **$475.00**

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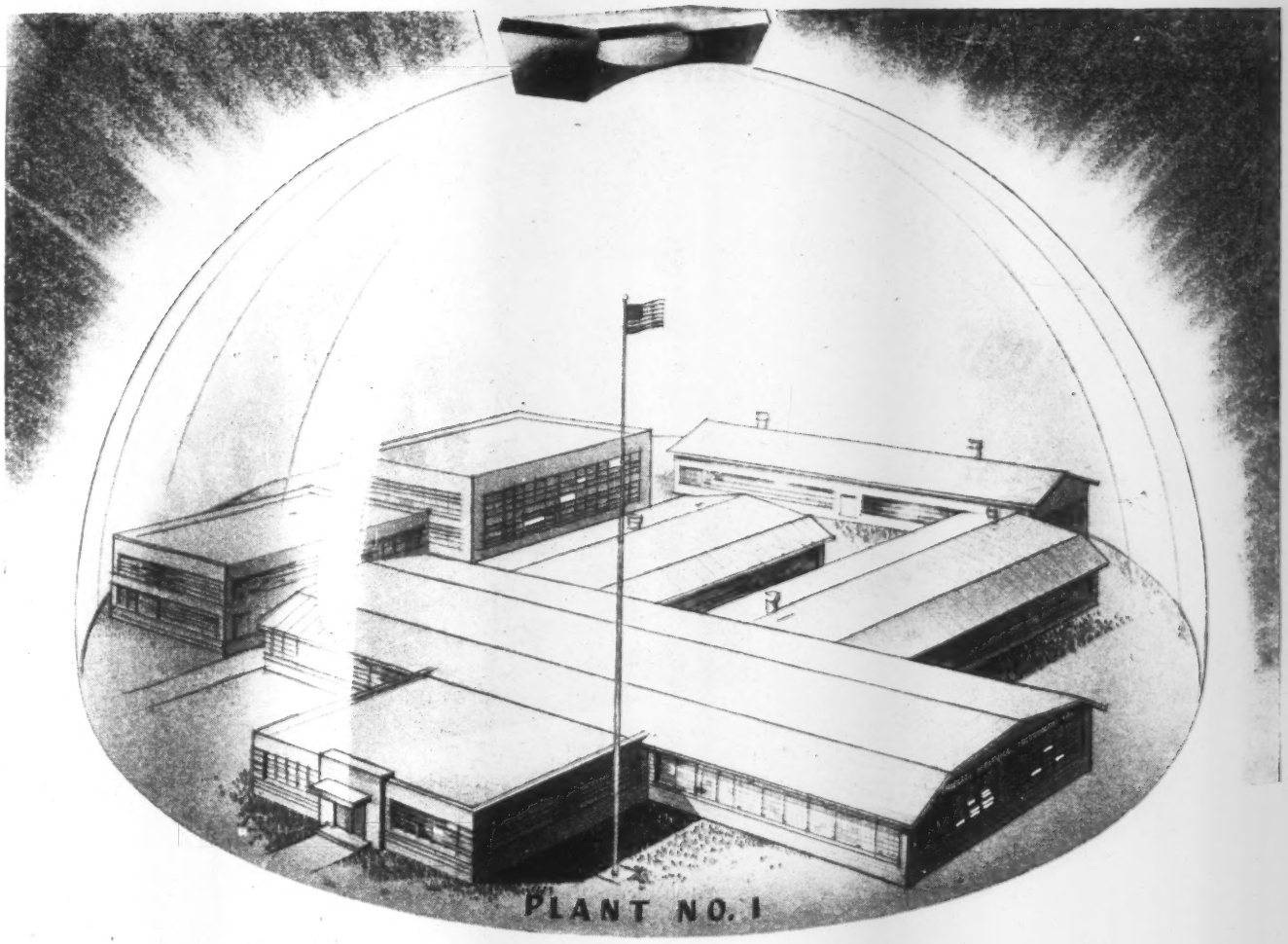

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For greater convenience, the catalog is divided into four sections, each with its tab-indexed cover. These sections comprise Mica Capacitors, Application Engineering Data, Paper Capacitors, Electrolytic Capacitors. The plastic binding permits pages to lie absolutely flat.

In preparation for a year and a half—involving widespread gathering of data and intensive compilation—this combination manual-catalog represents an outstanding contribution to the working library of the radio-electronic engineer and executive. It was prepared BY engineers FOR engineers; contains absolutely no advertising—just information on capacitance and capacitors. And because of cost, its circulation is strictly limited to engineers and executives.

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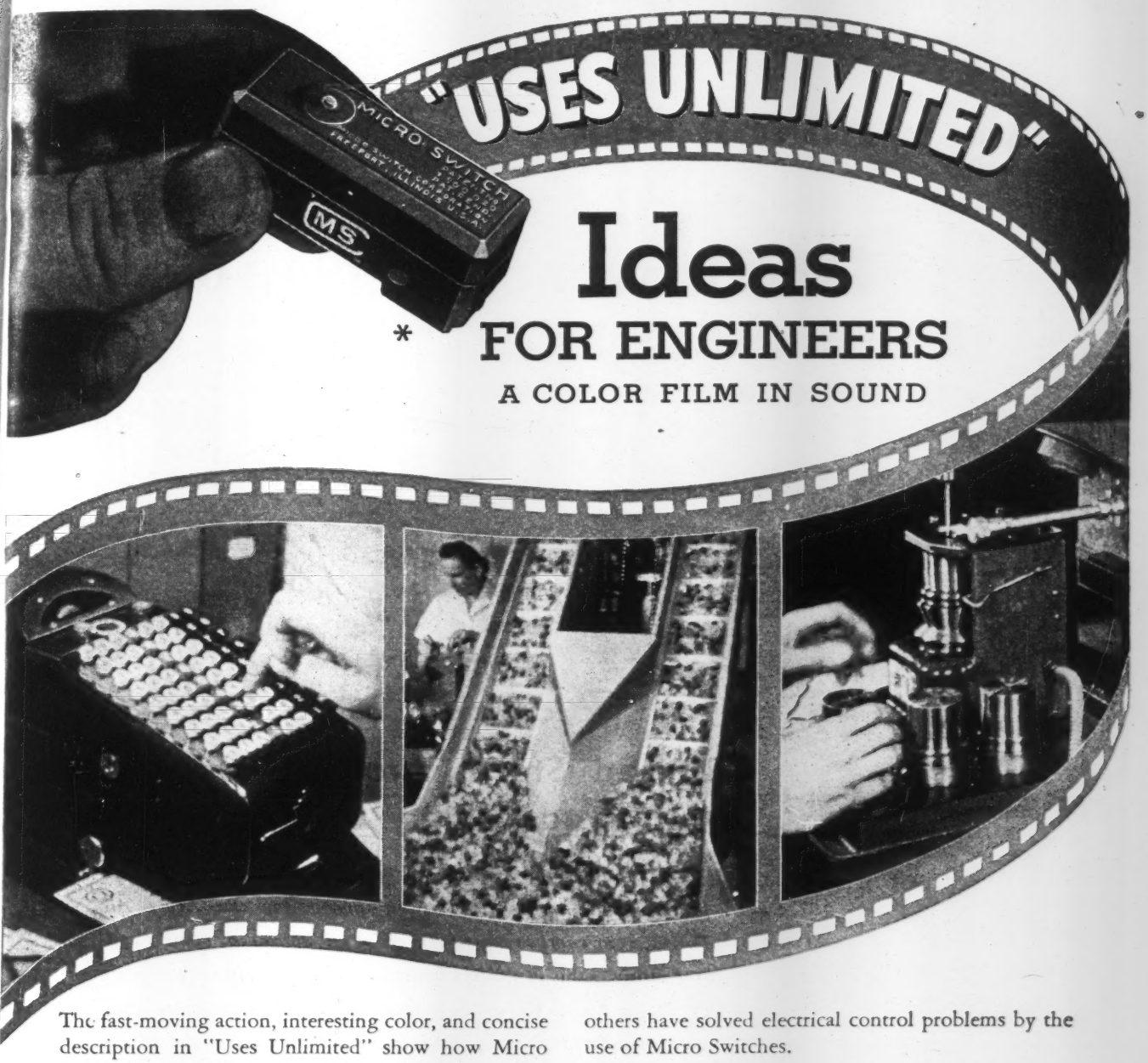

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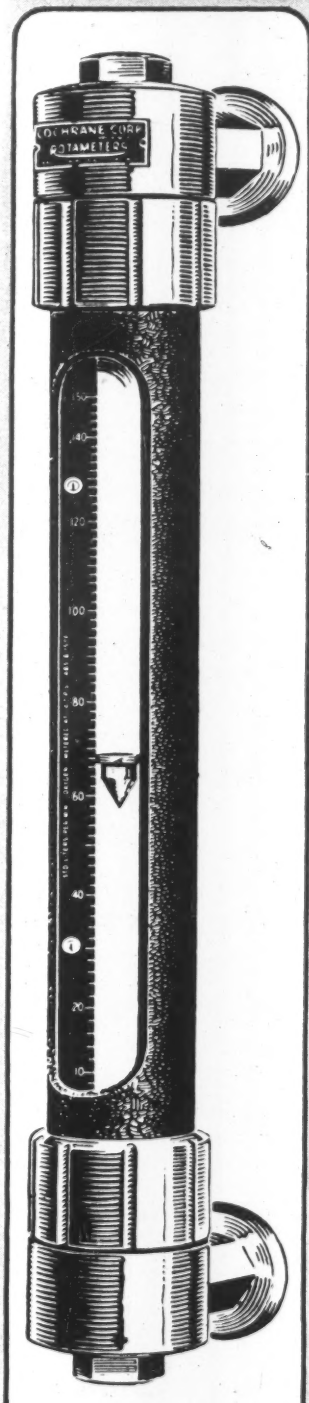

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FLOAT
ZERO LINE FOR SETTING SCALE IS ETCHED IN TUBE

Write for New Publication No. 4135

EASY TO CHANGE FROM ONE SERVICE TO ANOTHER . . . . WITHOUT CHANGING METERING TUBE

One important advantage of the Series 100 Rotameter is the interchangeable scales that make it possible to use the same Rotameter when it is desired to change from one service to another. New and accurate scales can be furnished quickly and inexpensively without loss of time and expense in returning meters for recalibration or new tubes and floats.

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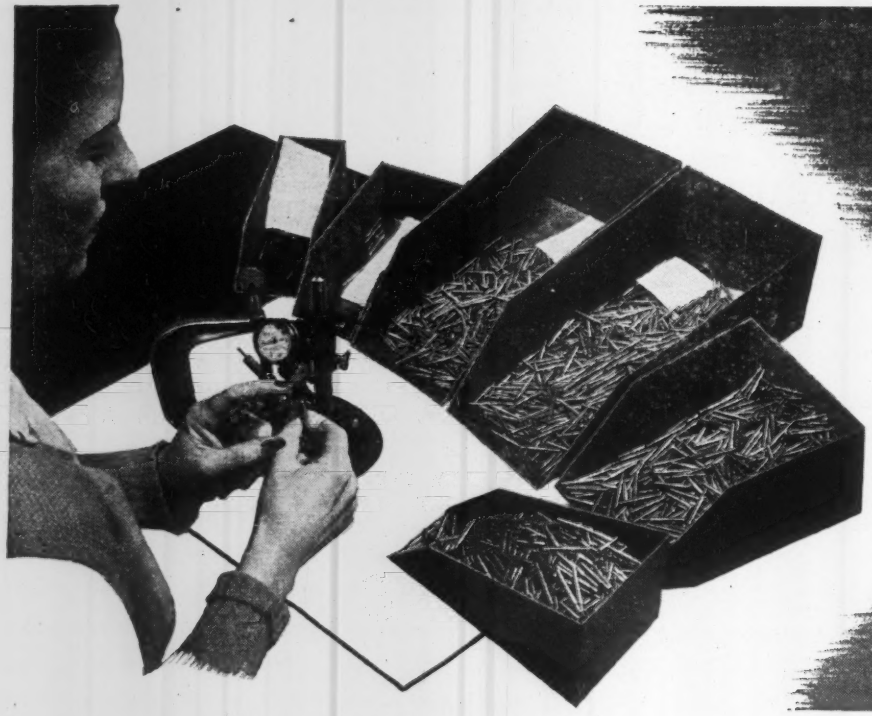

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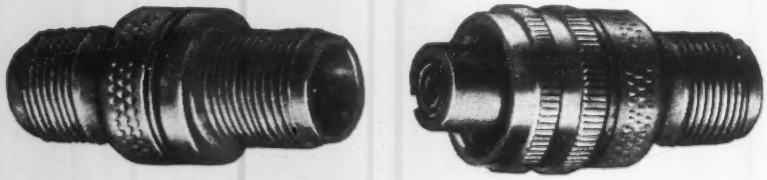
Cannon Quality Control adds plenty to our cost of manufacturing Cannon Plugs. We can't hold to such high production standards without paying for it.

But what is it worth?

When a set of flying instruments go dead in a soupy fog, when a motor konks out in a power dive, when a plane crashes with a loss of life—it's worth a lot to *us* to know that a Cannon Plug didn't cause the trouble.

And if such assurance is worth the extra time and better materials and added inspection cost to us, *how much more is it worth to the men directly involved?*

Your answer to that one is your best reason for using Cannon Plugs exclusively.



Type AN3101 (left) newest Cannon Connector is a portable receptacle which mates with AN3106 (right).

The bulletin on Cannon Type AN Connectors . . . gives a complete explanation of construction and operation of AN plugs. 96 pages with ample illustrations. Address Dept. A-123, Cannon Electric Development Co., Los Angeles 31, California.

CANNON ELECTRIC

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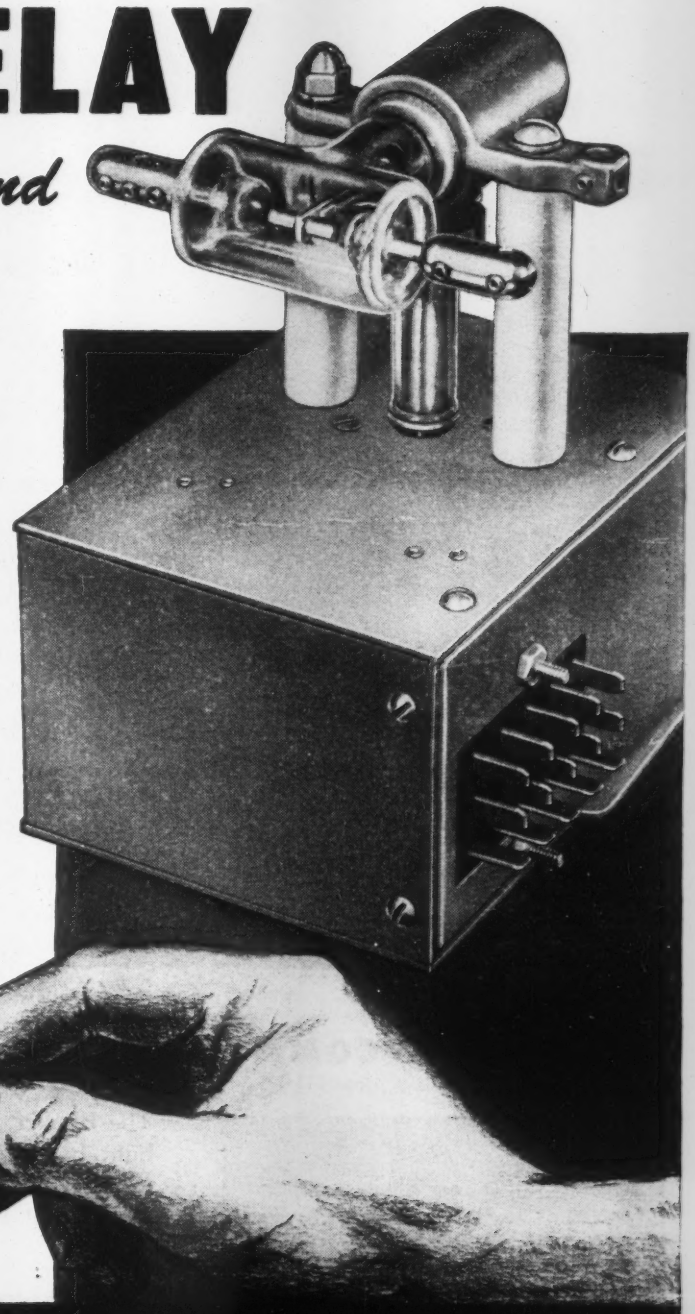
A New Vacuum Switch

KEYING RELAY

. . . . for Aircraft and Other Applications



Here is convincing proof that a keying relay does not have to be complicated to be efficient. In fact, just the reverse! Actually, the extreme reliability with which Struthers-Dunn Type 78CCA100 Relay holds its adjustments is the direct result of its new simplified and rigid design which utilizes an absolute minimum of parts.

Originally made for aircraft use, it weighs little, is exceptionally sturdy, and has all parts readily accessible. Tests show a minimum life of five million operations.

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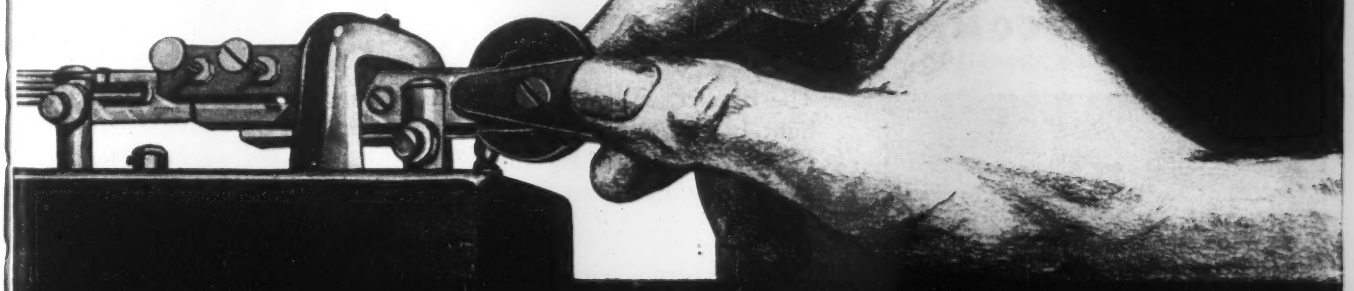

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History of Communications. Number Twelve of a Seri

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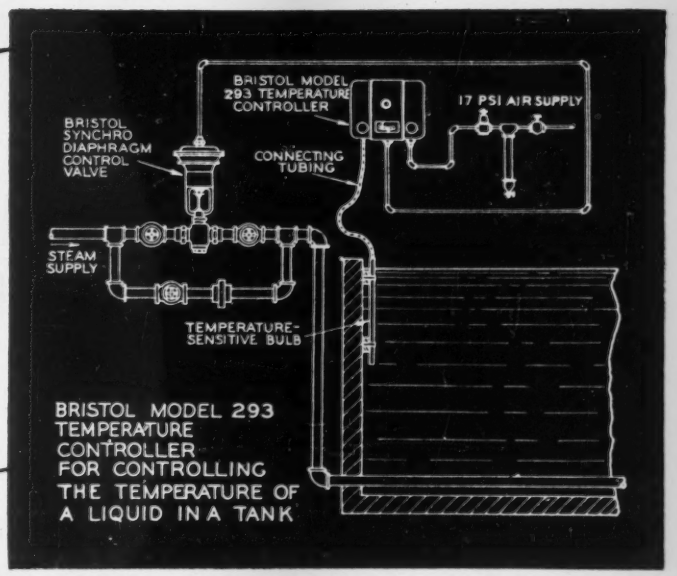
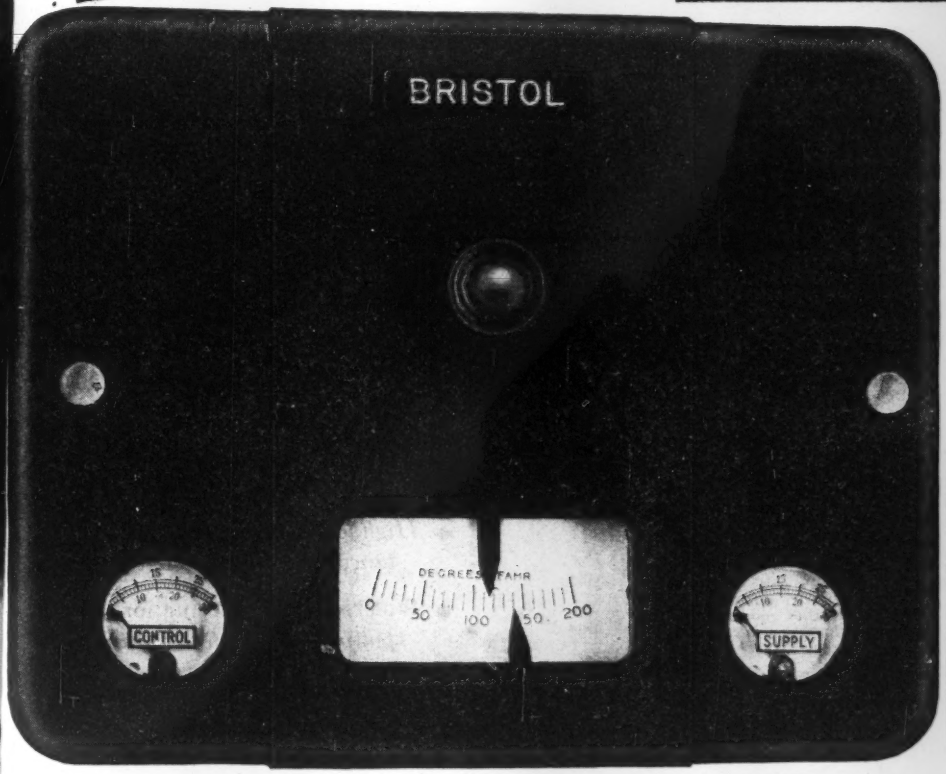
WHERE VARIABLES *must be controlled* BUT NOT NECESSARILY *recorded*


BRISTOL MODEL 293 TEMPERATURE CONTROLLER
17 PSI AIR SUPPLY
BRISTOL SYNCHRO DIAPHRAGM CONTROL VALVE
CONNECTING TUBING
STEAM SUPPLY
TEMPERATURE-SENSITIVE BULB
BRISTOL MODEL 293 TEMPERATURE CONTROLLER FOR CONTROLLING THE TEMPERATURE OF A LIQUID IN A TANK



Here ARE THE VARIABLES THE MODEL 93 CAN CONTROL

Temperatures
from −125° to 1000°F.

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from 0 to 100% R. H.

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of steam, gas, air and liquids through pipes.

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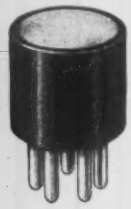
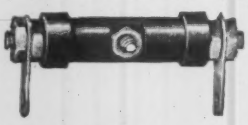
NEW RECTIFIERS FOR SIMPLIFICATION OF CIRCUIT DESIGN PROBLEMS

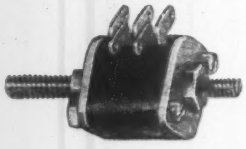
STANDARD MODELS OF COPROX RECTIFIERS



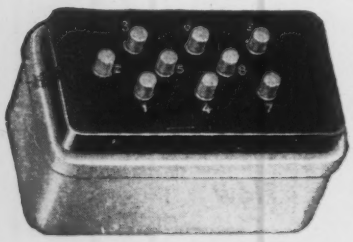
Coprox Model CX-2E4-A9, ring-connected and mounted in tube base, detects phase differentials in A.C. currents and small D.C. potentials applied to balanced A.C. circuits. Maximum 4.5 volts continuous. Shown here in actual size.



Coprox Model CX-1C2B1, a center tap, full wave rectifier. Completely enclosed in Bakelite. Low capacitance. Rectifies high frequency current. Conservatively rated up to 4.5 volts A.C., 3.0 volts D.C., 500 microamperes D.C. Other models and capacities to meet all needs.

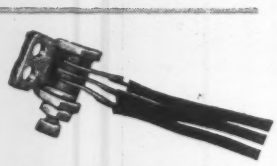


Coprox Model CX-4D4F23, a full wave rectifier with high conversion efficiency, for electronic control work. Rated at 5 volts A.C., 40 milliamperes D.C. continuous. Fully enclosed. Mounts on a single screw.



Coprox CX-3E8C3 double bridge rectifier with current and temperature current characteristics balanced to better than 1% over a range of —40°C to +70°C. Rated up to 4.5 volts A.C., 3 volts D.C. 5 milliamperes D.C. Other models and capacities to meet all needs

Coprox CX-2E1H5 (Not illustrated) Single half-wave rectifier rated up to 4.5 volts A.C., 3.0 volts D.C., 2.5 milliamperes D.C.



Coprox CX-2E2D4 (Above) Double half-wave rectifier rated up to 4.5 volts A.C., 3.0 volts D.C., 2.5 milliamperes D.C.

Coprox CX-2E4F2 (Not illustrated) Full wave rectifier rated up to 4.5 volts A.C., 3.0 volts D.C., 5 milliamperes D.C.

Many variations are possible with the basic Coprox Rectifier models described at the left. Bradley's application experience can help you, not only in the use of these units but also in the development and production of special rectifiers for special jobs. Here are the special features of all Bradley Coprox Rectifiers:

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- *Pre-soldered lead wires, or special terminals, to prevent overheating during assembly.*
- *High leakage, low forward resistance, for efficient operation.*
- *Waterproof lacquering or wax potting, for perfect sealing.*
- *Highly adaptable mountings.*
- *Ratings are very conservative.*

For samples and special data which will help you design more efficient circuits that will stand up longer than others, write Bradley. Ask any questions you have in mind.

LUXTRON PHOTOCELLS

A Bradley booklet is available, to suggest the many ways in which Luxtron* photocells can be used for control and testing purposes. These cells generate sufficient current to operate instruments and instrument relays without amplification. They, too, are built for long life and have varied mountings and a wide range of sizes. (*Trade Mark Reg. U. S. Pat. Off.)

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ENGINEERED DESIGN BY **HAMMEL-DAHL**

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- **Identical Stem Lengths for Either Action**
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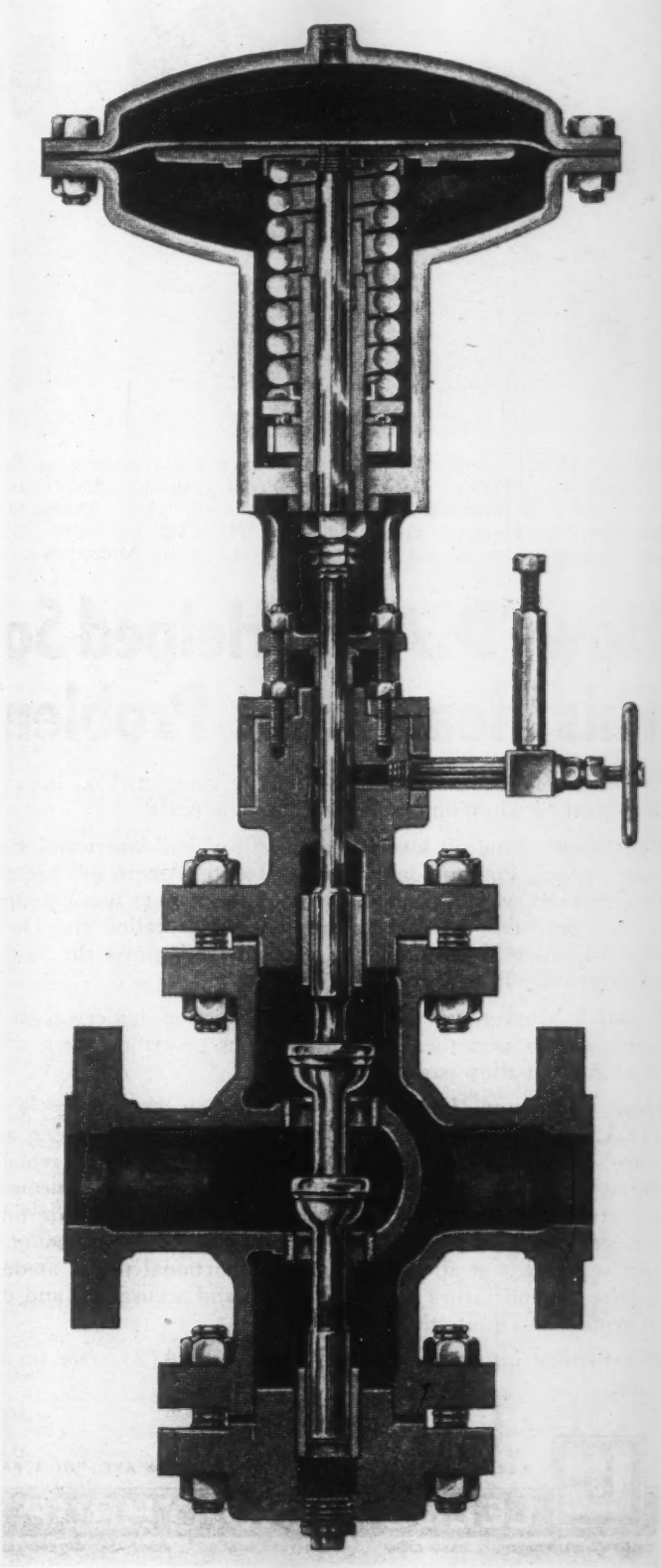

Available in sizes ½″ – 2″ screwed, 2″ – 16″ flanged. Valve Bodies of bronze, cast iron or cast steel Body and trim alloys to meet all industrial applications.

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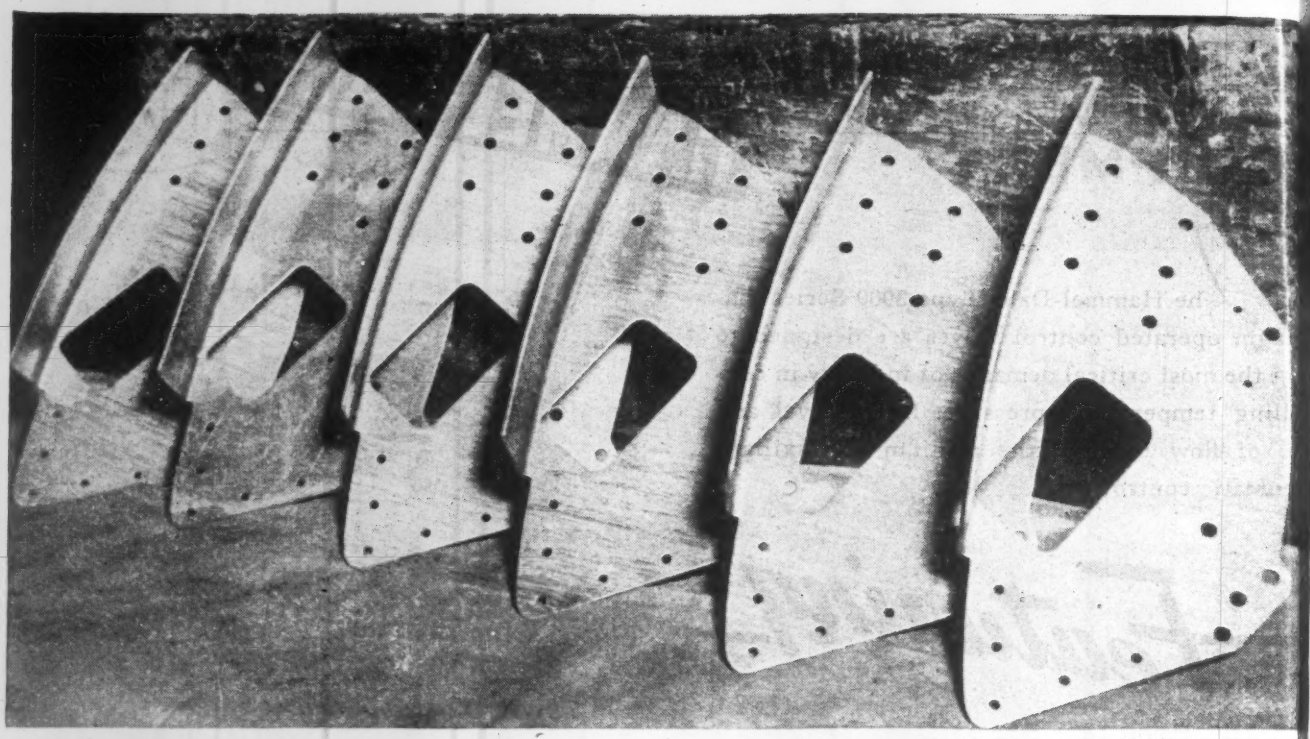
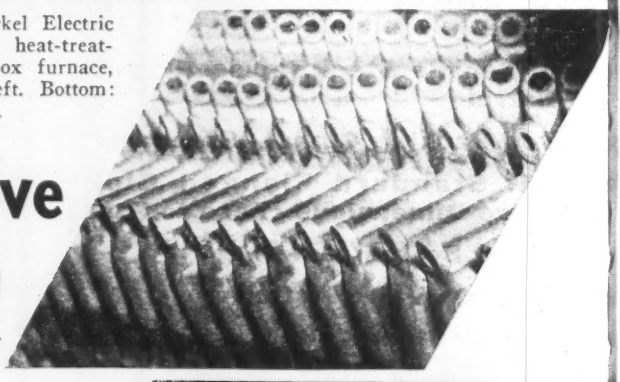


Above: Aluminum-alloy airplane parts after heat-treatment at Markel Electric Products Co., Buffalo, N. Y. Right: Pedal frame assemblies after heat-treatment and sand blasting. Center: Operator feeds pedal frames to box furnace, controlled by Duration Adjusting Type (D.A.T.) Controller at left. Bottom: Operator examines salt pot temperature record on the Micromax chart.



How "D.A.T." Helped Solve This Heat-Treat Problem

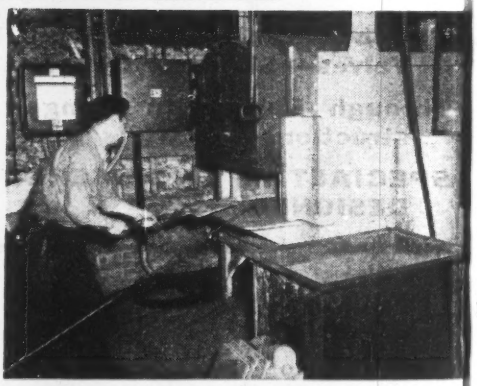
Problem: To equip the Markel Electric Products Co., Inc., for heat-treating aluminum and steel airplane parts.

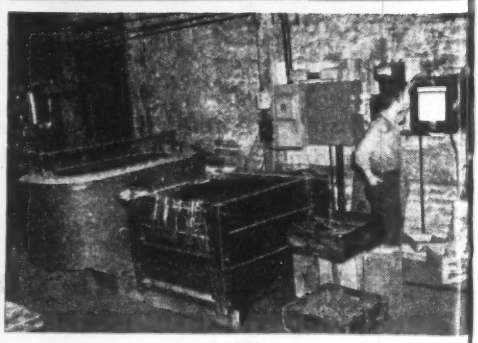
Equipment: One 60 kw, 466-amp, 208 volt "American" Furnace Co. Salt Pot, and one 36 kw, 100-amp "American" Electric Box Furnace were installed. Each of these units was equipped with a new type of Micromax Controller—called the Duration Adjusting Type—designed especially to improve the control of electrically heated units.

Results: Markel was able to get production underway with speed, and to meet the rigid specifications governing the quality of aluminum-alloy parts.

How Micromax Helps: These Duration Adjusting Type (D.A.T.) Micromax Controllers are considerably faster and more sensitive than any previous type—*because* D.A.T. replaces the mechanically-driven cam contactor with an instantaneously-operating electric circuit. Its automatic input regulator finds correct heating-up and holding rates *electrically*. The amount of heat supplied is at all times strictly proportional to the amount required; temperature is held smoothly and accurately and can be within any limits the user requires.

For further information, see Catalog N-00A(2), free on request.





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Jrl Ad N-00A(6)

Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

An Auspicious Start

IT IS fitting that the report of an intersociety conference should be printed on this page instead of on the Instrument Societies pages: it deserves prominent space.

It might have been equally fitting to print this report on the Instrument Societies pages: because it has been "on" those pages that members of local societies have been "meeting" every month since May 1942 when we printed the first Instrument Societies Calendar in addition to giving space to announcements (which he had been doing since 1939 when the first of these local societies was formed).

Secretary Darnell reports the "business" and naturally refrains from editorializing. I shall follow his example because I'm so enthusiastic about this federation movement that my undiluted praise might bore you. Fortunately, a calm evaluation appears in the latest newsletter mailed to all members of the Philadelphia group by their 1944 Secretary, J. E. Gambrill, who states:

"The advantages to the local membership to become affiliated in a national group were listed as follows: (1) Prestige of being a member of a National Organization; (2) The educational phase which should ultimately result in the improvement of the economic status of each member; (3) The cost of membership, which could only be measured in the value of the membership to each individual; (4) The social aspects in being associated with others interested in the same field who would be met at meetings, conventions and exhibits."

I need only add the benefits of members in plants remote from the cities where local groups meet monthly.—MFB

Report of Meeting on Proposed Formation of National Organization of Instrument Men

A CONFERENCE of representatives of eleven local measurement-and-control societies was held December 2, 1944, at the Men's Faculty Club, Columbia University, New York City. This meeting had been called by a committee of the American Society for Measurement and Control of Pittsburgh; and invitations had been sent to all the known local instrument, electronic and measurement-and-control societies, asking them to send representatives.

Professor C. F. Kayan, of Columbia University and the New York Society for Measurement and Control, opened the meeting and extended a hearty welcome to those present.

A. H. Shafer, Chairman of the Committee of the Pittsburgh Society that was responsible for the meeting, stated the purpose of the conference and called the roll of the societies. Those present were:

AMERICAN SOCIETY FOR MEASUREMENT AND CONTROL (Pittsburgh)
*A. H. Shafer, The Foxboro Co.;
M. F. Behar, Instruments Publishing Co.;
Paul G. Exline, Gulf Research & Development Co.;
Richard Rimbach, Instruments Publishing Co.

BALTIMORE INDUSTRIAL INSTRUMENTATION SOCIETY
*L. A. Bruns, Calvert Distilling Co.;
**J. F. Maienshein, Brown Instrument Co.

CANADIAN SOCIETY FOR MEASUREMENT AND CONTROL
*T. C. Agnew, Minneapolis Regulator Co., Ltd.

CHICAGO SOCIETY FOR MEASUREMENT AND CONTROL
*Earl C. Rieger, Int'l Harvester Co.;
**Hugh E. Ferguson, People's Gas Light & Coke Co.

HARTFORD SOCIETY FOR MEASUREMENT AND CONTROL
*Stephen J. Zelle, Bridgeport Thermostat Co., Inc.

INSTRUMENT SOCIETY OF WASHINGTON (D. C.)
*Richard C. Darnell;
**A. H. Mears, U. S. Weather Bureau.

INSTRUMENT SOCIETY OF WAYNE COUNTY (Wyandotte, Mich.)
*R. A. Wright, Metrol Co.

NEW YORK SOCIETY FOR MEASUREMENT AND CONTROL
*C. O. Fairchild, C. J. Tagliabue Mfg. Co.;
**C. F. Kayan, Columbia University;
Robert Farnham, N. Y. Office of Instruments Publishing Co.;
A. L. Hildenbrand, Esterline-Angus Co.
Stuart Rogers, N. Y. Office of Instruments Publishing Co.;

PHILADELPHIA SOCIETY FOR INSTRUMENTATIONS
J. E. Gambrill, Moore Products Co.;
George Hammer, Foxboro Co.;
M. H. White, Atlantic Refining Co.;
W. D. Young, Barrett Div. Allied Chem. & Dye Corp.

ST. LOUIS SOCIETY FOR INSTRUMENTATION
*H. B. Freeman, Economy Equipment Co.

SOCIETY FOR MEASUREMENT AND CONTROL (NEW JERSEY)
*Harry F. Moore, Standard Oil Development Co.;
**R. F. Roberts, Brown Instrument Co.;
Sidney Baran, Radio Corporation of America;
Robert H. Gray, Standard Oil Development Co.;
H. S. Close, Titanium Div., National Lead Co.

GUESTS
Albert F. Sperry, Hubbard Engineering Co., Chicago, Ill.;
Ralph D. Webb, Carbide & Carbon Chemical Corp., South Charleston, W. Va.

* Delegate ** Alternate

Dr. C. O. Fairchild, President of the New York Society for Measurement and Control, was unanimously elected Chairman and R. C. Darnell (Washington) was appointed Recording Secretary for the meeting.

Richard Rimbach (Pittsburgh) upon the request of the Chair gave a brief history of the growth of the local instrument societies in this country.

Representatives of the different societies were then called upon to state their views as to the desirability and nature of a national society devoted to the field of measurement and control. Although the opinions expressed varied as to the detailed nature and scope of a national society, the sentiment in favor of proceeding with its organization was unanimous.

A committee was elected to prepare a draft of a constitution of the proposed society for submission at the next general conference of delegates. The committee is composed of H. F. Moore (New Jersey), M. H. White (Philadelphia) and R. C. Darnell (Washington), chairman. The committee chairman appointed C. O. Fairchild (New York), Richard Rimbach (Pittsburgh) and W. A. Wildhack (Washington) as advisory members of the Constitution Committee.

Chicago was decided on as the place of the next meeting. The date decided on is February 17, 1945. Earl C. Reiger and Hugh E. Ferguson, both of Chicago, were elected Chairman and Vice-Chairman respectively of this Chicago meeting. R. C. Darnell was elected to continue as Recording Secretary.

Inquiries regarding the Chicago meeting or other details of the proposed society should be addressed to the Chairman, Earl C. Rieger, 2626 West 31st Blvd., Chicago, Illinois; or to the Recording Secretary, R. C. Darnell, Box 4730, Washington, D. C.

—R. C. DARNELL, *Recording Secretary*

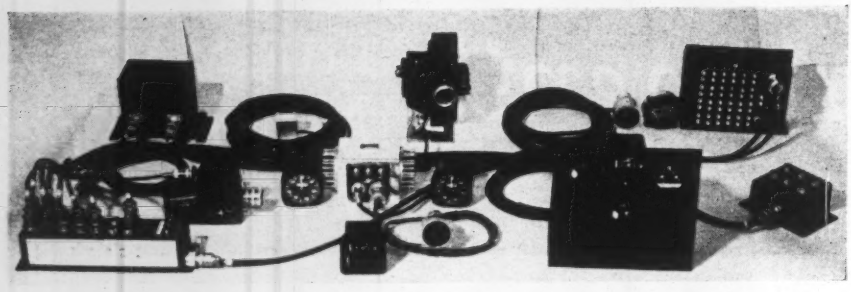


Fig. 1. Some of the components of Bell automatic flight-test instrumentation.

Automatic Flight-research Instrumentation of the Single-seater Fighter

By STEPHEN B. ELGGREN, Senior Flight Instrumentation Engineer, Bell Aircraft Corp., Buffalo, N. Y.

SINCE the much-needed production of our newest type of aircraft demands an early and complete preview of performance, it is mandatory that complete and automatic instrumentation be installed in all such aircraft so that the maximum amount of data on the operation of the engines, controls, and aircraft performance may be secured with a minimum of prototype flight testing. When the near impossibility of maintaining constant flight-operating conditions over any sustained test period and the vital importance of the time element during flight testing are compared with the great amount of valuable data sometimes wasted yet capable of being obtained during each hour of flight testing, the necessity for securing these data with a minimum of flight testing is seen in its true light. It is toward this goal of complete, accurate, and automatic flight instrumentation that the industry is striving, and the Bell Aircraft Corporation developments in flight instrumentation have been accomplished with this view in mind.

The requirements of flight instrumentation vary widely according to proposed uses, but the greatest restrictive requirements are probably embodied in complete flight research programs of small high-performance aircraft. Suitable instrumentation for such tests must be small, light, compact, versatile, and easily installed. It must have stable performance throughout wide variations of temperature, pressure, attitude, acceleration and voltage supply; and must also be isolated against vibration. Because of the vast amount of data required during each flight, this type of instrumentation must be completely automatic and capable of recording by one or more methods —such as photography, printing or stylus recording, electrical transcription, etc.—so that detailed analyses of the data may later be made.

In large aircraft installations the instrumentation requirements of smallness, lightness, and compactness are somewhat relaxed. However, the necessity for securing flight-test data from many and varied sources in the airplane rapidly enough to present a complete and true survey of the phenomena being measured clearly obviates the continued use of flight personnel for data-recording operations. Since large flight crews are undesirable and continuously-recorded data are often required under unfavorable human conditions, the optimum combination is to have a bare minimum of flight personnel observe the operations and results of completely automatic instrumentation rather than record personally the data from manually-operated devices.

Presented at the Radio and Instrument Session, Twelfth Annual Meeting, Institute of the Aeronautical Sciences. Copyright 1944 by the Institute of the Aeronautical Sciences, Inc.

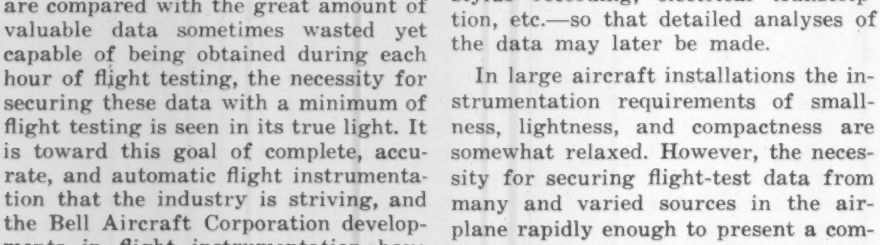


Fig. 2. Single-impulse intervalometer and control.

Bell Automatic Instrumentation

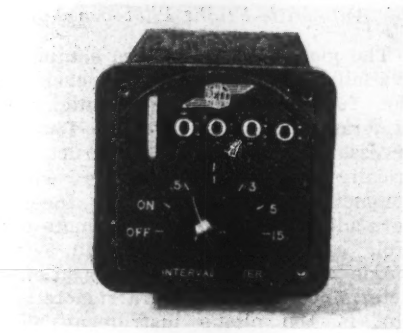
In order to secure flight-test data that will lend themselves most readily to complete and true analysis, the instrumentation must be capable of receiving, transducing, indicating, and, finally, recording many physical stimuli at closely-controlled and correlated time intervals. Also, since automatic operation is immediately dictated by the nature of the tests, devices are necessary which will reliably control and actuate all component parts of any instrument installation at specified time intervals. Development of the Bell automatic flight instrumentation system is the result of such a need, and many of these instrumentation systems have been used successfully during the past year of flight testing (Fig. 1).

This system provides complete and continuous photorecorder surveys of multiple pressures, temperatures, positions, forces, stresses, attitudes, accelerations, speeds, etc. Its operation is automatic and is remotely controlled from the pilot's cabin. Since versatility and standardization of instrument installation and operation are prime requirements, these features have been incorporated into the design of the equipment mentioned above.

Basically, it consists of electrically-actuated pressure and temperature switch advance instruments and their appropriate indicators, an electronic intervalometer to govern the intervals of automatic instrument actuation, electrified cameras to record photographically the flight-test data, counters and identification light units for proper correlation of time, and also of the particular survey points being recorded, and a complete set of remote controls for versatile application to flight research sequence and operations.

Electronic Intervalometer

The intervalometer is an electronic device designed to operate automatic flight instrumentation (Fig. 2). Its principles of operation are those of gas-filled electronic tubes, together with the



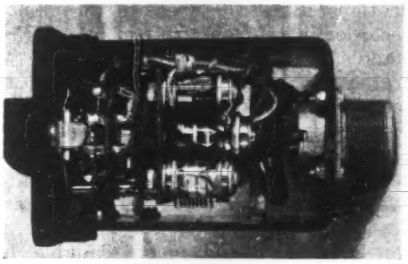


Fig. 3. Single-impulse intervalometer control.

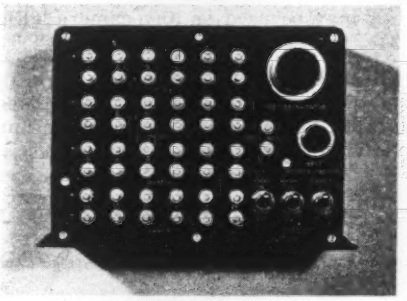


Fig. 4. Banking-type electrical selector switch.

Fig. 5. Air-scoop pressure distribution survey.

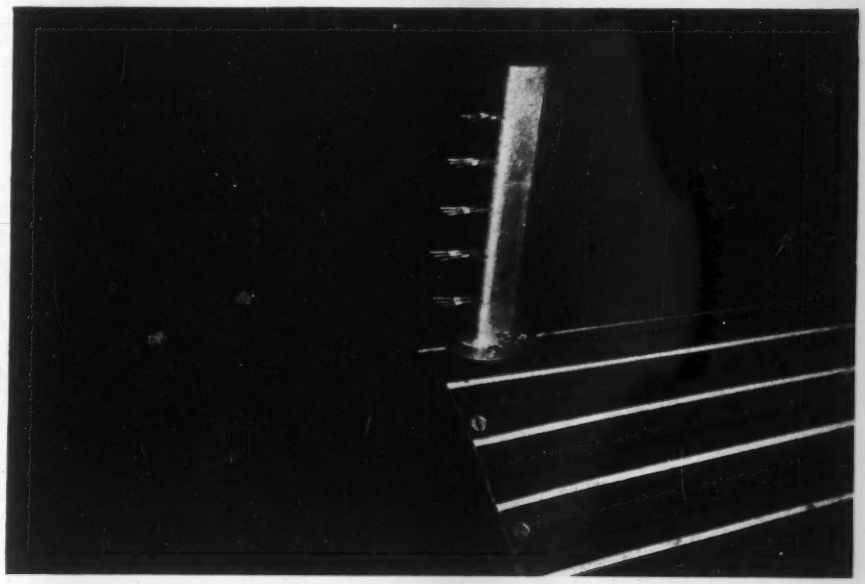


Fig. 6. Carburetor intake pressure survey.

time-delay characteristics of a resistor and capacitor connected in series in this thyratron circuit. Essentially, a gas-filled tetrode is caused to conduct, and the resulting flow of plate current within the tube is used to energize a sensitive time-delay relay. This delay period is approximately 0.2 sec. When its contacts close, power is supplied to a second relay, which in turn performs the switching functions necessary for the automatic flight instrumentation system. When the power relay is energized, the external circuits receive an impulse, the time-delay circuit capacitor is charged, and the plate circuit of the gas tube is broken, causing an interruption in its plate current. The time-delay relay and the power relay are thereby permitted to open. This procedure places the voltage of the time-delay circuit on the grid of the tube (i.e., the negative side to the grid), opens the contacts of the external circuit, and replaces the plate voltage on the tube. The negative potential on the grid is allowed to leak off slowly at a rate determined by the delay resistor in the remote-control head (Fig. 3). This leak continues until a critical value of negative grid voltage is reached, at which point the gas-filled tube again conducts current and the cycle is repeated. The remote control allows interval selection at will by the pilot of ½-, 1-, 3-, 5-, and 15-sec. duration. Since this instrument operates directly from the low-voltage aircraft power source, it does not include rotating or vibrator-type power supplies normally required in electronic flight equipment. This type of intervalometer is relatively insensitive to variations of voltage, temperature, pressure, acceleration, etc., and has exhibited reliable and accurate performances throughout the past year of flight testing.

Automatic Pressure and Electrical Advancing Switches

The automatic pressure and electrical switch advance instruments are capable of 48-point surveys, and the interval between each survey point may be determined by the intervalometer remote controls (Figs. 4, 5, 6 and 7). Some special flight tests do not require a full complement of 48 pressure or temperature points in the desired surveys. Consequently, "banking" features allow only portions of the points to become "active"; the remaining ones are "passed" in such rapid succession that no indication is registered on the indicating instruments connected to the electrically-operated switch advance units. Therefore, valuable flight and instrumentation time is not wasted

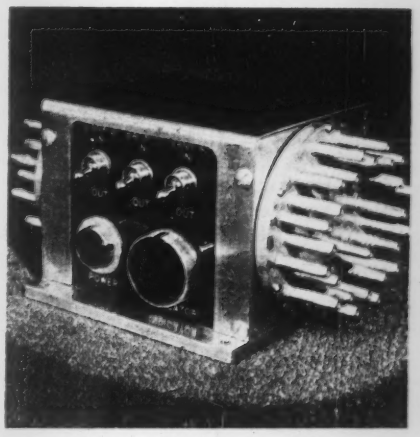


Fig. 7. Banking-type electrically operated air switch.

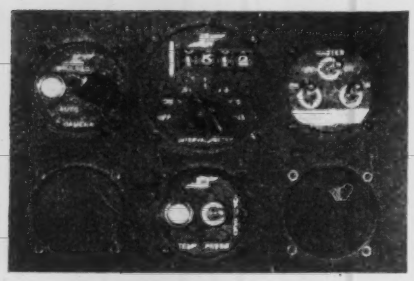


Fig. 8. Controls for Bell automatic flight instrumentation.

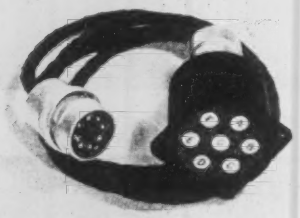


Fig. 9. Identification light unit.

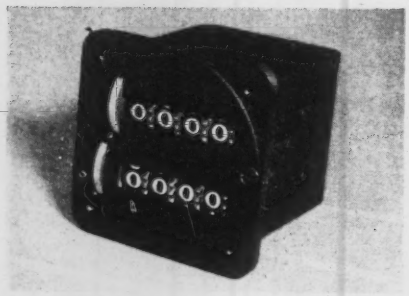


Fig. 10. Flush panel mounting type dual counter.

when fewer than the maximum number of data points are required.

Often flight-testing programs require one complete survey of all pertinent data at many different stabilized conditions of flight, such as altitude, speed, climb, attitude, acceleration, and power. Accordingly, these survey switches are capable of automatically advancing through one complete cycle of required data points and then stopping on a "home position." The next cycle of survey points is started by a push button on the remote control in the pilot's panel when he has attained the next stabilized flight condition specified. The use of these selector switches allows complete coverage of pressure and electrical surveys characteristic of flight testing if the flight stimuli under observation are not changing rapidly enough to introduce error into the survey data because of the short-time intervals between selector switch positions and the inherent dynamic limitations of the indicating instruments being used.

Remote-control Flight Instrumentation

Since space available for experimental instrumentation in the cabin of the Bell P-39, P-63, and other single-seater fighter airplanes is at a premium, it is imperative that flight-test data be recorded by automatic instrumentation somewhere in the airplane other than on the pilot's instrument panel and that only the minimum amount of flight-instrumentation remote controls be placed in the airplane cabin. Remote control units, as described above, allow complete control and operation of this automatic instrumentation (Fig. 8). It is only necessary to place the appropriate controls in a position accessible to the pilot and he is thereby capable of controlling the manner in which the required flight-test data are secured. The manner in which data are recorded from the remote-control unit may be either continuous or impulsed in operation, as determined by the nature of the flight testing being conducted. When operated under impulsed conditions, the instrumentation may be actuated steadily by regulated interval impulses or it may be cyclic, as noted in the description of the air or electrical switch advance units.

Automatic instrumentation permits the pilot to devote his entire attention and activities to his actual test flying, a full-sized job in itself. Such instrumentation thereby relieves him of all the encumbrances that previously required him to operate the flight equipment and to record manually the rapidly-fluctuating flight data from his own instrument panel. Data secured by the pilot alone are, in general, inadequate when considered in the light of the great amount of flight-test data available by automatic instrumentation, the actual cost and importance of flight-test operations, and the relatively small percentage cost required for complete instrumentation of all flight-research programs.

Correlation of Photorecorder Data

Proper identification of survey flight-test data being indicated in the photorecorder is important if such information is to be used for analysis. To provide this positive identification and correlation with time, electric circuits have been designed in the switch advance instruments and appropriate electrical signals are sent through cables to identification light units, which are placed next to the switch advance indicating instruments in the photorecorder (Fig. 9).

By supplying current to various combinations of the dial lights of the identification light unit, a maximum number of 63 separate data points can be identified. For further correlation of flight data,[4] electrically actuated counters are incorporated into the design of the intervalometer remote-control unit and similar dual counters are placed in the photorecorder (Fig. 10). These counters are not cyclic in operation, as are the identification light units described above, but are actuated by separate impulses from the intervalometer and total each impulse consecutively.

Automatic Flight Photography

The most suitable camera equipment available on the market has never met the full requirements of flight-test cameras. Accordingly, we have found it necessary to design and construct electrically-actuated mechanisms within commercial-type cameras to incorporate additional features of remote control, continuous rewind, and either single-frame or continuous operation as determined by the camera remote control in the pilot's instrument panel (Figs. 11 and 12). These camera modifications allow pictures of the photorecorder instruments to be conveniently made at intervals ranging from 64 frames per sec. to 1 frame every 60 sec., as dictated by the nature of the flight-test data desired. Photorecorder installations require wide-angle lenses because of the limited space normally available in modern single-seater fighters and the necessity for maintaining the maximum and most readable instrument data possible. Standard mounts have been designed for wide-angle lenses of various types so that they may be used on any camera (Fig. 13).

Because of the extensive work involved in reducing a series of flight-test data to a suitable form to allow final analytic comparison, any excessive

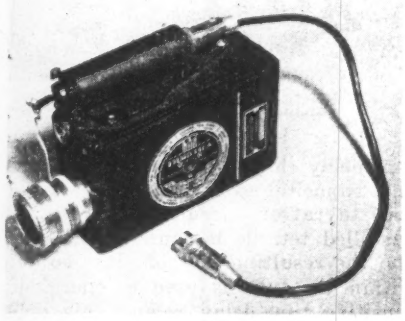


Fig. 11. Electrically-actuated Filmo 16-mm. camera altered to allow either single-frame or continuous operation.

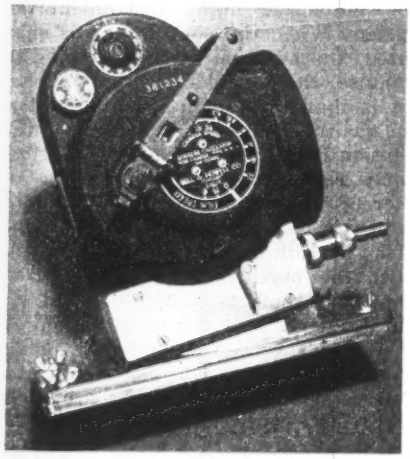


Fig. 12. Electrically-actuated Eyemo 35-mm. camera altered to allow single-frame and continuous operation.

time delay in film handling and developing is an appreciable expense and, accordingly, must be held to an irreducible minimum. By standardizing our procedures we are able to have photorecorder film developed and ready for use 45 min. after the test airplane has landed.

Power and Control Junction Box

The power and control junction box is primarily a piece of equipment designed to supply, in a convenient manner, both power and control to all of the automatic instrumentation components, such as air switches, electric switches, cameras, intervalometer, etc., and their remote control units (Figs. 1 and 14). This feature allows standardized cables to be used for all probable combinations of flight-test instrumentation programs and required sequences of operation.

Airplane Control Force Instrumentation

Electromagnetic strain gages form the basis of our airplane control force instrumentation, and the power supplies, oscillators, amplifiers, and indicators were designed around these transducing gages (Fig. 15). In brief, a small deflection in the control stick or rudder tube changes the impedance of the accurately-wound and -positioned armature coils within the special electromagnetic strain gages, and this impedance change is then amplified to a workable value. The output of the gages is fed directly to the grids of a twin triode tube which form the two variable arms of a balanced bridge. The indicating instruments are in this bridge circuit. In effect, the 1,000-cycle carrier signal is modulated by minute

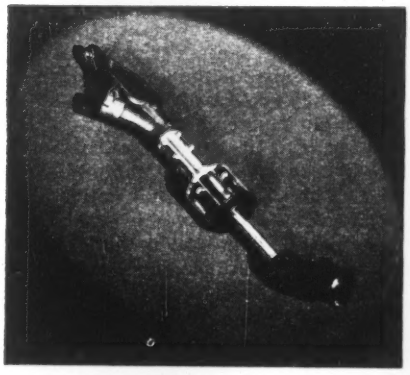


Fig. 15. Electromagnetic strain-gage-type elevator and aileron control-force transmitter.

deflections of the electromagnetic strain gages, and the indicating circuit senses both magnitude and direction of the applied control force. The range of forces measurable by this instrumentation is practically unlimited since the gages can conveniently indicate deflections as small as 0.0001" and the actual deflection is a function of the physical characteristics of the members being strained (Figs. 16-22).

Redesigned Electrical Instruments

In order to secure control-force measurements in their most useful form, it is necessary to have indicating instru-

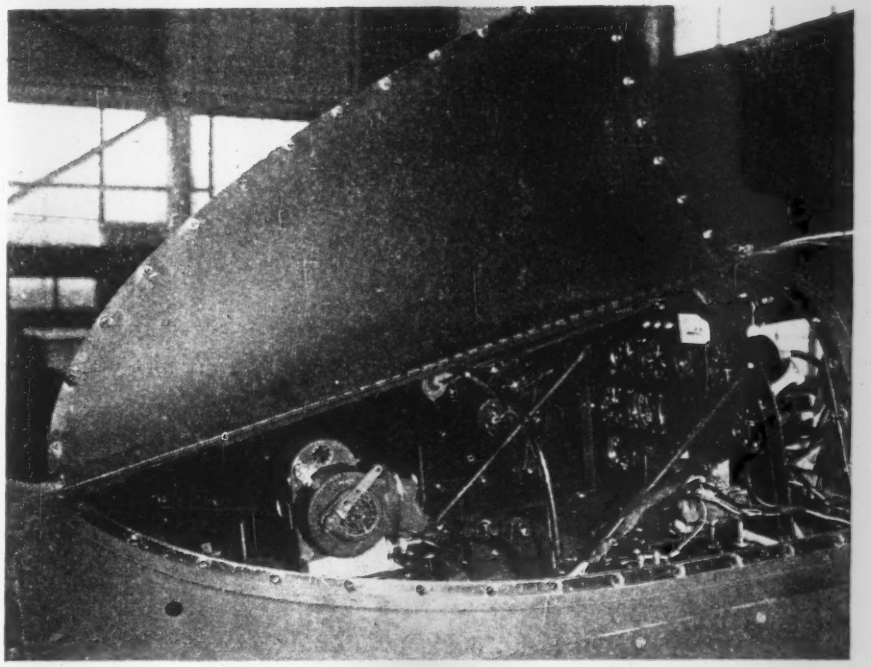


Fig. 13. P-39 aft cabin-type photorecorder installation.

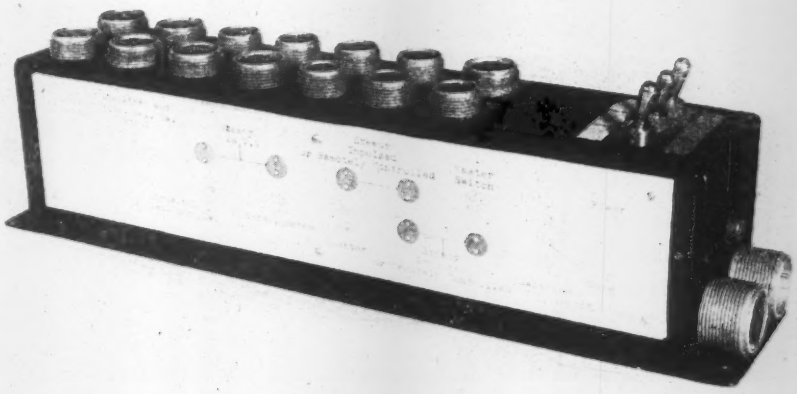


Fig. 14. Main junction box.

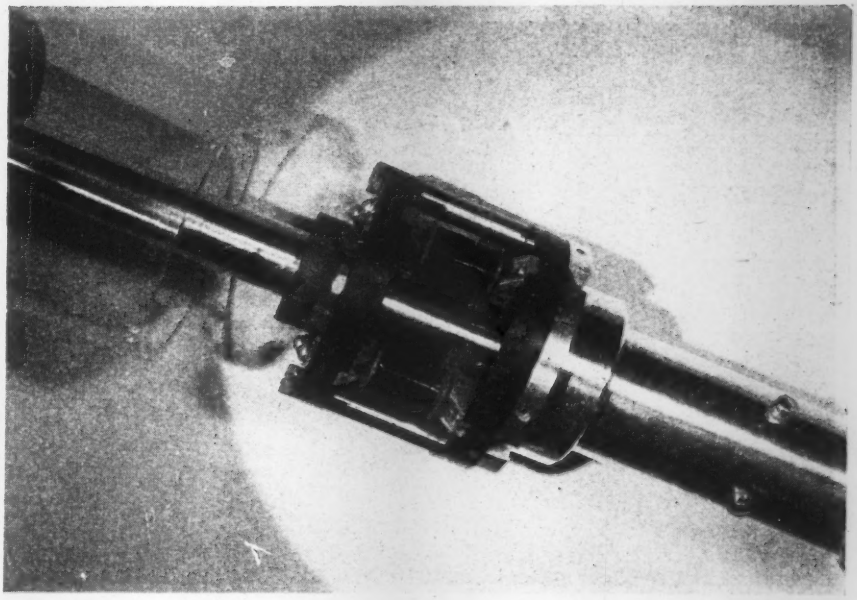


Fig. 16. Close-up of control-stock-force transmitter, showing details of coils, laminations, and supports.

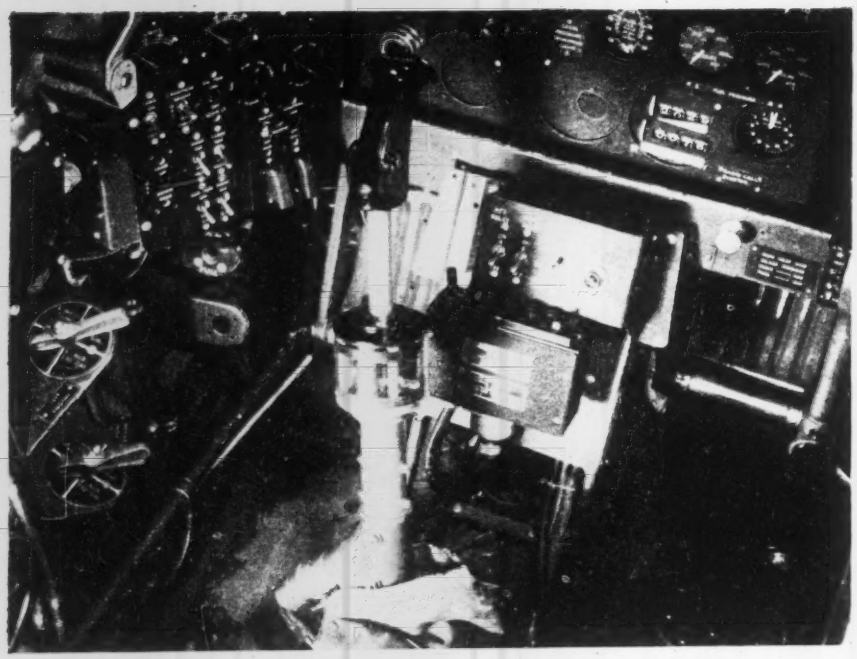


Fig. 17. Airplane installation of Bell control stick force transmitter.

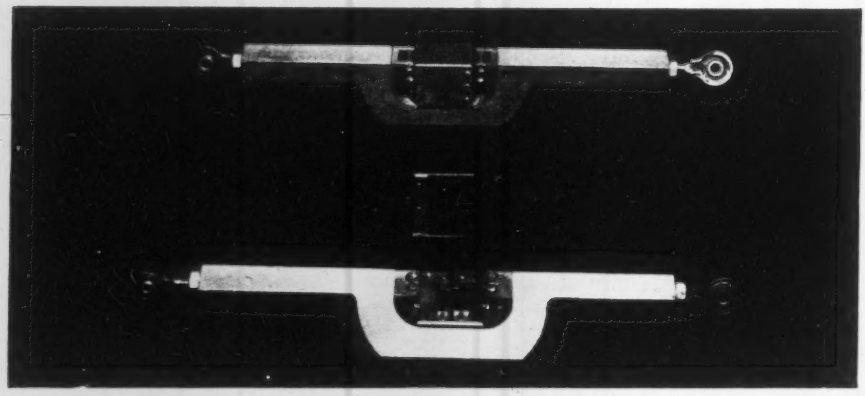


Fig. 18. Electromagnetic strain-gage-type rudder-force transmitters.

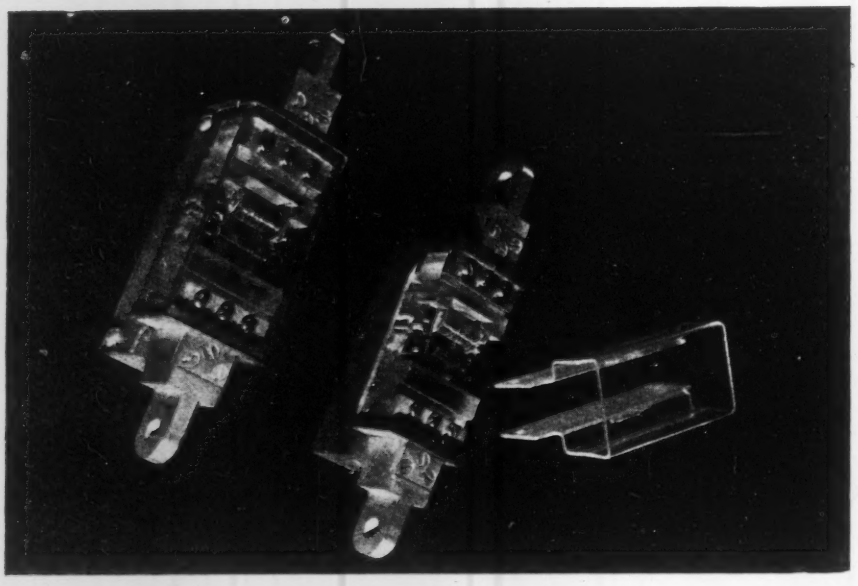


Fig. 19. Electromagnetic strain-gage-type rudder-force transmitters.

ments of high sensitivity and fast action. Moreover, the indications must be suitable for photorecorder installations. Deflection-type electrical instruments capable of indicating variations of signal strength five to seven times per second and of sufficient scale length to allow satisfactory sensitivity are not available on the market; therefore it was necessary to redesign and alter instruments obtainable from normal sources of supply. The redesigning of these instruments consisted of casting and machining new-type Alnico magnets to provide much stronger magnetic fields, of rewinding the armature coils with considerably more turns of 0.001"-diameter fine wire, and of replacing the pivot hair springs with much stronger units. New dials were constructed with an overall range of 100 lbs., and with this scale it was possible to indicate force measurements with a sensitivity as great as 1 lb. in 100 lbs. The sensitivity, accuracy and dynamic properties of these instruments, as altered, proved to be well within the requirements of airplane control force indicating instruments. Many sets of this control force instrumentation have been constructed and used during experimental flight testing with successful results.

Electronic Carrier-bridge Flight Instrumentation

A relatively simple method of generating electrical intelligence as a function of any specified physical stimulus under observation has been developed in the Electronics Laboratory. In addition to producing dynamic or static indications and being comparatively small in physical size, its output is unaffected by wide variations of carrier-wave frequency, amplitude, and wave-form. The intelligence-generating component of this flight instrumentation is a balanced carrier bridge whose arms are designed to be sensitive to changes of any desired physical stimulus under observation. The sensitive bridge pickup arms may be based upon changes of resistance, capacitance, or inductance—whichever parameter lends itself best to registering the required stimuli. The system can be arranged to supply indi-

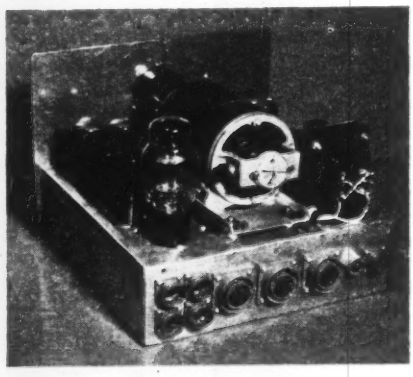


Fig. 20. Top inside view of Bell four-channel oscillator-amplifier airplane control force instrumentation.

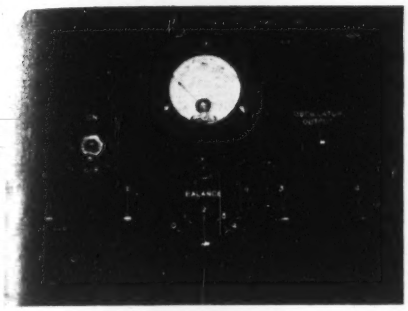


Fig. 21. Bell four-channel oscillator-amplifier airplane control force instrumentation.

tion through deflection-type instruments, tape recorders, oscillographs, or cathode-ray tubes, as dictated by the nature of the flight research program.

The output of the unbalanced bridge is an audio-frequency carrier whose amplitude is a function of bridge unbalance and input carrier amplitude. This output is amplified and fed to a compensated copper-oxide rectifier circuit producing direct current for indication. Variations in carrier amplitude which are normally reflected in the indicator as erroneous readings are automatically compensated for by feeding a portion of the original carrier voltage to a diode rectifier. The resulting direct current is applied as a negative control potential in the amplifier. Thus, the signal available for indication is independent of carrier-amplitude variations. Opposite direction or force discrimination is recognized by the instrumentation and is based on the fact that the output of the a-c. bridge undergoes a phase reversal of 180° as the balance passes through zero. A phase-conscious discriminator is therefore incorporated in the copper-oxide rectifier so that the polarity of the d-c. output reverses when the phase is reversed. Since the two voltages from the amplifier and oscillator originate from a common source, the electrical addition or subtraction of the vector components as determined by their phase relationship in the discriminator circuit is independent of carrier frequency and wave-form.

As noted before, variations of carrier frequency, amplitude, and wave-form do not produce erroneous indications, and therefore a small rotary d-c. inverter is used as the power and oscillator source. Multiple channels of this type of instrumentation for specified flight testing portend substantial savings in space and installation time.

Automatic Temperature Recording

An automatic Brown pyro-potentiometer (Fig. 23) has been used in flight testing for the past year. As a result of this testing, alterations were found necessary in order to render the instrument suitable for reliable operation in small high-performance, pursuit aircraft. Briefly, these changes provided for remote control and indexing for flight-test data correlation; appropriate circuit changes to allow resistance-type

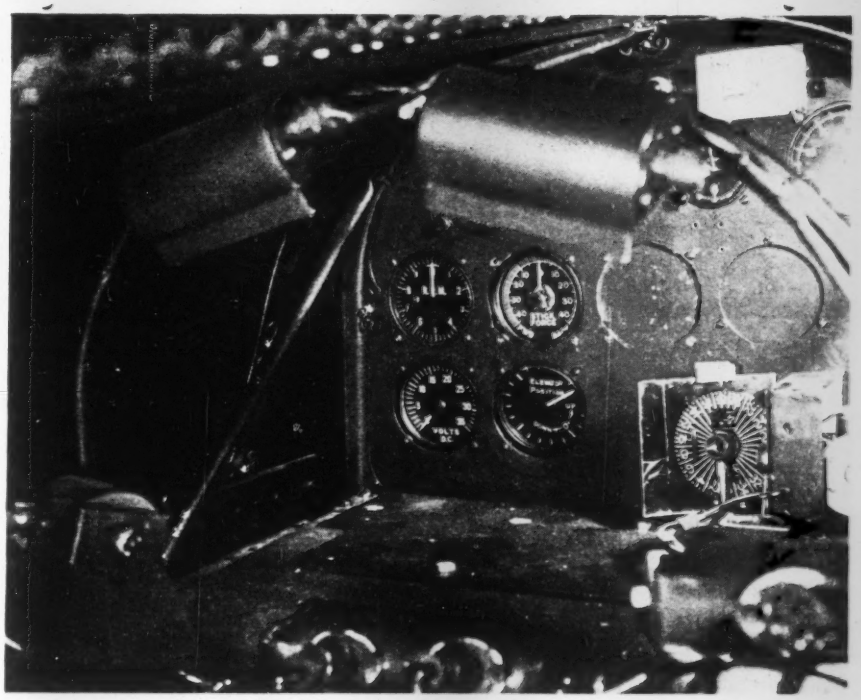


Fig. 22. Photorecorder installation showing elevator stick force, elevator position, and gyro adapted to indicate rate of pitch.

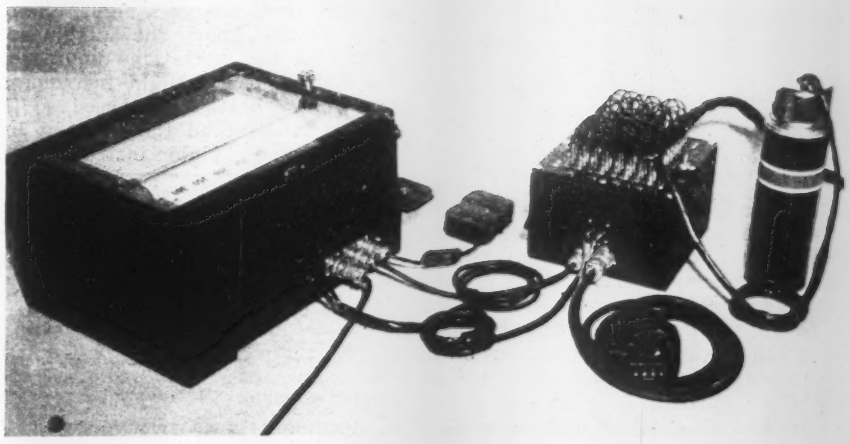


Fig. 23. Brown temperature recorder system.

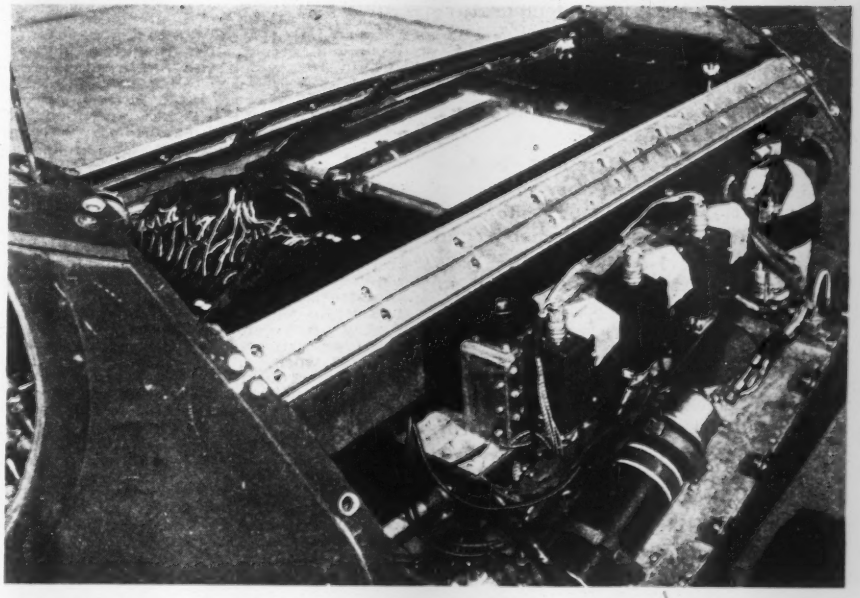


Fig. 24. Typical P-39 automatic temperature survey instrumentation.

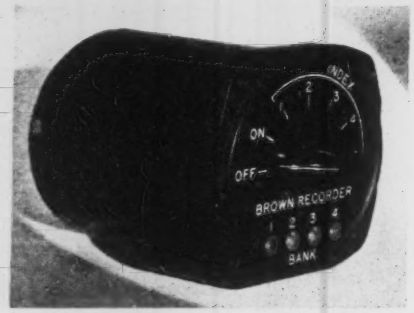


Fig. 25. Remote control for Brown automatic temperature recorder.

strain-gage measurements for position, altitude, air-speed, and force indications; and extensive revisions in the thermocouple lead switch boxes to eliminate error-producing thermoelectric effects in the dissimilar metal terminals due to the temperature differentials at these points caused by the rapid ambient temperature changes experienced by high-performance pursuit aircraft as they are flown through their rigorous flight tests. (See Figs. 24 and 25.) When airplane space available for instrumentation does not permit or when flight testing does not require temperature surveys as extensive as that possible with a Brown recorder installation, the electrical advancing switches described previously are used in combination with other Bell automatic instrumentation at a proportionate saving in installation time.

Flight Instrumentation Requirements

The designer of flight-research instrumentation is confronted with perhaps the greatest combination of error-producing variables ever presented as an instrumentation problem. A few of the most important variables to which flight instrumentation must necessarily be made insensitive are as follows:

(A) Temperature—Flight instrumentation must exhibit true compensation and complete accuracy of all indications throughout a temperature range of +75° to —65°C.

(B) Pressure and Density—Satisfactory operation and indication must be maintained throughout a pressure range of 2 to 15 lbs./in.^{2}.

(C) Vibration—Instrument components must exhibit reliable operation and indication even though subjected to vibrations of high intensity and large amplitude throughout the wide frequency spectrum characteristic of combinations of reciprocating engines, gear boxes, propellers, and aircraft structures. The ratio of power developed to engine-mounting weight for small aircraft far exceeds all other power installations, and the resulting vibration problem is aggravated proportionately.

(D) Supply Voltage—Flight instrumentation must be capable of producing true indication of measured stimuli regardless of supply voltage variations of ±15%.

(E) Attitude and Acceleration—All instrumentation must be designed to be unaffected by rapid changes in attitudes and sustained or cyclic acceleration loads from —4*g* to +9*g*.

Current Instrumentation Developments

Major developmental programs of particular interest to Bell Aircraft Corporation and presently receiving the attention of its Flight Research Division include, among others, the following: (A) flight thrustmeter instrumentation; (B) flight engine detonation instrumentation; (C) flight torquemeter instrumentation; (D) electronic frequency meter tachometers; (E) cathode-ray photorecording; and (F) continuous-line dynamic flight recorders.

Conclusion

As the field of flight instrumentation increases in scope, intensity, and purpose, it becomes readily apparent that the instrumentation development engineer must know the fundamental theories and principles underlying the phenomena that he is attempting to explore. This knowledge must necessarily include aerodynamics, mechanics, dynamics, structural analysis, electronics, etc. It also follows that the engineer who analyzes flight research data should know the fundamental principles and operations upon which the many types of flight instrumentation "black boxes" are based so that he may understand the inherent limitations of all flight instrumentation and interpret the results accordingly. The engineer who analyzes flight research data with such a basic knowledge of flight instrumentation principles is more likely to glean the maximum amount of useful information from any set of flight-test data, and he is less likely to arrive at erroneous conclusions because of wrong interpretations of both normal and abnormal instrumentation operations. Moreover, a fundamental understanding of this nature also allows instrumentation to be used to its fullest capabilities.

Although flight instrumentation has advanced considerably with regard to increasing the sensitivity and accuracy of flight-data measurements and in broadening the scope of flight testing and data recording, it is still an infant when compared with most other types of instrumentation. Intensive research and further development are therefore dictated for flight instrumentation, and appropriate paths of endeavor are:

(1) Development of continuous-line recorders to secure the desired flight-test data by means of continuous lines on a roll of paper, which *data are ready for immediate observation and evaluation by the flight research engineer.* This instrumentation may be designed to operate either in the aircraft during flight or at ground stations that are controlled by radio transmission of flight data from aircraft. The true economy of the expenditure of money and developmental time for such time-

Institute of the Aeronautical Sciences

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saving instrumentation is plainly evident when it is compared with present inefficient methods of film developing, reading and plotting in continuous-line form prior to any analysis whatsoever.

(2) Development toward increased sensitivity, range, and accuracy within practical limits.

(3) Development and simplification of dynamic-type instrumentation. The present systems of dynamic flight instrumentation consist of mechanical stylus or torsion-wire galvanometer-type recording oscillographs and multiple cathode-ray tube photorecorders, and present users of this instrumentation would welcome a developmental program devoted to its simplification.

The field of aircraft dynamics is progressively encompassing a larger variety of design and flight research activities and, as a result, a considerable amount of research work has been done in the development of suitable dynamic-type flight instrumentation. *It is especially important to note that progress has been made in this field of research only as rapidly as appropriate flight instrumentation has been designed, developed, and flown to secure the dynamic flight-test data required.* This situation is typical of the relationship of all research to instrumentation problems, and the aircraft industry in general will be well repaid if it establishes and promotes organizations to design and develop instrumentation to meet the many present and future needs in this field. *Every advancement in the field of flight instrumentation opens vistas for research into new flight phenomena and is therefore a notable contribution to the aeronautical sciences.*

During any flight test program the effective *"quantity of answers" is a direct function of the speed with which data can be secured for analysis. It is evident that even an unlimited supply of capable engineering manpower will not increase the number or speed of these answers that directly affect all engineering, production, and corporate finances if these flight research data are not forthcoming in sufficient quantity.* Delays in production result in losses sustained by the manufacturer and may be evaluated on the basis of the profit normally earned per airplane times the number of planes affected by the delay. *Facts indicate that with a production of 70 planes per month, valued at $750,000 each, a three months' delay could result in a loss in excess of $1,000,000 to the manufacturer.* Accordingly, instrumentation must be available and properly used so that the desired answers may be obtained immediately after the completion of a flight. Long-range preparation of instrumentation is therefore necessary so that appropriate data may be obtained quickly and accurately.

We at Bell Aircraft Corporation have discovered extensive uses for our

(Concluded on page 44)

Testing Vibrating Contacts

By CHAS. E. DIEHL, Elec. Eng'g Dept., Columbia Steel Co., Geneva, Utah

VIBRATING-CONTACT instruments that furnish automatic control through variation of the ratio between time open and time closed have many inherent ills but these need not cause headaches if the contacts are properly maintained.

Rapidly-vibrating contacts affect an electric circuit as though they were replaced by a resistance because the time ratio variation, summed up over a period of ten or fifty on-and-off cycles, is effectively a variation of resistance. This effective resistance can be measured by means of an ammeter in series and a voltmeter shunting the moving contacts. By means of the average values indicated and the use of Ohm's Law the resistance can be shown. However, for servicing the contacts, a well-damped voltmeter of the proper range is all that is needed.

Since the moving contacts furnish a variable resistance, anything that affects the actual or instantaneous contact resistance in any manner will cause the instrument to fail to function correctly. A change in the contact pressure will change the effective resistance, increased pressure acting as a resistance decrease, and vice versa. Pitted and misaligned or dirty contacts will increase resistance.

The method of establishing proper operating conditions is to shunt the contacts with the proper voltmeter and observe the average voltages as indicated during proper operation of the instrument. Time ratios may be calculated by measuring full-open contact voltage. The percent of open time will then be equivalent to the percent of full voltage indicated by the voltmeter. Closed time is of course the difference between this value and 100%.

Once having observed proper values, future contact troubles can be diagnosed by making readings and observing how these differ from the proper values. If the contacts are moving slowly or the instrument has a too-rapid response, the instrument cannot indicate an average by reason of continual swings. As the important thing is the ratio between time open and time closed, this ratio can be maintained through a large variation of speed of vibration of the contacts. Therefore, a speed of vibration fast enough to give a steady reading on a good instrument will be found to be much more effective in any kind of control work.

Suppressed-zero Voltmeters

By H. S. EDGERLY,

Panel and Equipment Div., Philadelphia Works, General Electric Co.

CAN better accuracy be obtained over a particular range in voltmeter readings by zero suppression? The answer is no. As a matter of fact, it decreases the accuracy.

Let us take, for example, a 150-volt voltmeter commonly used on a battery circuit. The opinion has been that more accurate readings could be obtained if the zero were suppressed and a full scale range of 100 to 150 volts used, thus increasing the distance between divisions.

The voltmeter element has been designed to exert a definite torque over a given scale length or angular deflection, 0 to 150-volts. Now, regardless of where the mechanical zero is set, the element still exerts the same torque for a specified applied voltage; therefore this becomes a constant factor. If the zero is suppressed so that the 100-volt point on the scale is located where the mechanical zero was previously located, then the torque available to move the needle from 100 to 150 volts is only 50/150 or ⅓ that previously available to move it from 0 to 150 volts.

The errors arise from the fact that the friction in both cases is the same and, therefore, the potential errors will be increased in proportion to the zero suppression.

Apart from these increased errors, other factors make suppressed-zero instruments undesirable:

A so-called "spring drift" may occur in instrument springs. If such a condition occurs it cannot be immediately determined, nor will it ever be discovered in a suppressed-zero instrument unless the instrument is given a calibration test. Hence, the readings may be in error for quite a length of time without being detected. With a mechanical zero it will be noticed at once on deenergizing the instrument.

There are several other conditions that could prevail to cause change in calibration that, like the above instance, could not be detected in a suppressed-zero instrument unless a periodic calibration is established as a routine affair.

Good instrument practice, therefore, dictates the necessity of having a definite zero in position on the scale.

[EDITOR'S NOTE.—Our old subscribers, who know the distinction between "accuracy" and "sensitivity," are certainly not the ones who express the "opinion" to which Mr. Edgerly refers: he must have heard it from people who don't read *Instruments* at all and who think that the suppressed-zero principle used in ALL THERMOMETERS (0°Abs. has never been attained) and in most frequency meters, etc., can be utilized in deflection voltmeters.—M. F. BEHAR]

ELECTRIC GAGING METHODS for Strain, Movement, Pressure and Vibration

By HOWARD C. ROBERTS, Research Staff, Association of American Railroads, Chicago, Ill.

V. GAGING METHODS BASED ON VARIATIONS OF RESISTANCE.

(Concluded)

§7. SENSITIVITY.

In general, the variable-resistance gaging systems are intrinsically less sensitive than either the variable-inductance or the variable-capacitance systems. A more precise statement is that the percentage change in gage impedance for equal movements is smaller with the variable-resistance gaging element than with either of the other two types. This characteristic requires either that indicating instruments of high current sensitivity be used, or that amplifying devices be used with indicators of lower sensitivity.

There are two basic reasons for the lower intrinsic sensitivity of the variable-resistance gage. One is that it is not possible to confine the movements being measured to an air gap of small dimensions, and thus to cause the percentage change (of the air-gap) to become large; the other is that it is not possible except in very special circumstances to take advantage of particular electrical phenomena—the resonance effect with capacitative systems or the change in Q (ratio of impedance to resistance) in inductive systems.

With moving-contact and with thermosensitive primary elements there is a considerable difference between maximum gage sensitivity and usable gage sensitivity, because of the inevitable random errors occurring in the pick-up units. (These errors occur also with strain-sensitive elements, but to a far smaller degree.) It is hardly practicable*, for example, to employ a moving-contact resistance element to measure movements to an accuracy of 0.0001″, because of mechanical irregularities of the moving contact and the resistance element, the effect of dust, etc. This is an instance in which constructional difficulties make the operating sensitivity far lower than the theoretical maximum sensitivity.

No benefit is derived from employing a sensitivity so high that random effects confuse the data; the final accuracy is not thus increased, although the difficulties of operation are. The maximum usable sensitivity is dependent to this extent upon the short-time stability of the primary element.

The sensitivity to be expected from a particular variable-resistance gaging element depends upon its form as well as upon the skill employed in its construction. Slidewire elements, for example (Figs. 64A, 64B, 79, 83, and 88A), may easily be made sensitive to movements of 0.01″; and without great difficulty to 0.001″. This presupposes the use of indicating instruments of high current sensitivity so that the moving contact need not carry appreciable current, and also that non-amalgamating resistance materials be used with mercury-contact forms of primary elements.

At the other end of the scale, moving-contact devices employing tapped resistance elements, such as those of Figs. 64C, 64D, 65B, 85 and 86, seldom are expected to measure small displacements, although they can be so constructed as to make such measurements possible. (The form of Fig. 65B, for example, can easily be made sensitive to movements of 0.005″.) These elements ordinarily are intended to measure relatively large movements under difficult operating conditions. They also have the advantage of not requiring an electrical calibration. By arranging the contact array in a circular endless form, reduction gears may sometimes be installed to increase the movement at the primary element, and thus the operating sensitivity; if a servo-system is employed in conjunction with such an arrangement, both high accuracy and robustness are made available.[208]

Thermosensitive elements can be constructed to have extremely high intrinsic sensitivity, although this may be obtained only at the expense of shortening the range. One commercial Pirani-Hale vacuum gage is supplied calibrated over a range of 0 to 10 microns and is considered accurate to 0.1 micron, or about 0.00000394″ of mercury.[209] Hot-wire instruments, such as the Heurtley magnifier, the Shakespear micrometer, or the Tucker hot-wire microphone can be made with comparable sensitivities. Since the sensitivity of such devices is closely related to mechanical design and construction, and specifically to the dimensions which govern the flow of heat within the unit, the intrinsic sensitivity of such units is directly related to the care used in their construction.

The sensitivity of resistance thermometer elements and of electric hygrometers depends primarily upon the characteristics of the materials used in their construction. Certain liquid (electrolytic) resistance materials have extremely high temperature coefficients of resistivity, and consequently may be used to construct extremely sensitive elements. With many automatic-control systems employing resistance thermometers as primary elements, control to 0.01° F. is possible. (This means that the primary-element sensitivity is even better—which is not astonishing when it is remembered that platinum resistance elements with an ultimate sensitivity of a millionth of a degree were made by nineteenth-century astronomers.)

The sensitivity of strain-sensitive elements, too, depends upon the characteristics of the material of which they are made. While with any resistance material a change in resistance results from a change in the geometry of the unit, with most solid materials resistance changes also result from changes in stress intensity. (See Section 4.) In practice, the materials which have been most satisfactory afford a resistance change approximately twice as great as the change in dimension[163] (both figures in percent). Thus, the intrinsic sensitivity of such elements is rather low. Their high stability, however, largely counteracts this as a disadvantage by making possible the use of indicating instruments of high current sensitivity.

As with other types of electric gaging systems, the sensitivity of a resistance-type system depends partly upon the sensitivity of the indicating instrument. When amplifiers are used, the amplifier characteristics predominate over all others in determining the performance of the overall system. In non-amplified systems, the current (or potential) sensitivity of the indicating instrument is a factor of great importance, since a lack of sensitivity at that point in the system cannot be counteracted in any other manner. The physical requirements of the particular application usually determine the sort of indicating instrument which can be employed. Pointer-type instruments requiring only a few microamperes for full-scale deflection are now available.

Selection of the most suitable electric circuit is essential if the highest sensitivity is required. Series circuits are not capable of sensitivity nearly so high as that of bridge circuits, because in the bridge circuit the large standing current is balanced out and, since only the variations in current appear at the indicating instrument its total scale range can be low—its sensitivity high. The very highest sensitivity, in a non-amplified circuit, is ordinarily obtained

*Although with mercury-contact variable-resistance elements even higher sensitivity has been attained.

(208) P. P. Schilovsky. Slow Speed Precision Training Governed at a Distance. *Journal of Scientific Instruments*, (London), Vol. 2, 1924, pages 23-25.

(209) H. H. Zielinski. Measurement of High Vacuums. *Electronics*, Vol. 17, July 1944, pages 112-115.

f a sensitive potentiometer is employed to balance a ridge-type circuit used in a null method. In general this rovides the highest accuracy as well.

In electric gaging practice, it is not uncommon to em- loy Wheatstone bridge circuits with four nominally equal rms. When it is necessary to employ arms of widely dif- ering resistances, the greatest sensitivity is obtained hen the battery (or other source of exciting energy) and he indicating instrument are properly connected; the best rrangement is with the element having the greater resist- nce connected between the junction of the two arms hav- ng the greater resistance and the junction of the two arms aving the lesser resistance. Interchanging the position of he source and the detector can make a considerable differ- ence in the circuit sensitivity.

It is possible, of course, to make a gaging system so sensitive that the random variations occurring in the pri- mary element appear as indications comparable to the total range of the indicating instrument. Sensitivity so high as this is of little value; for ordinary use the great- est accuracy is obtained when the random errors produce deflections less than 5% of the instrument scale range.

§8. Stability.

Gaging systems operating with variable-resistance primary elements are troubled by instability in just the same manner as others; there are, however, more sources of instability which must be guarded against.

Instability, of course, is the effect of random variations in the operating parameters of the electric circuit, and in the impedance of the primary element. (Discussion here will be limited to the instabilities of the primary elements.) In the foregoing sections, the effect of factors such as change of temperature and change of dimension has been described; in each instance because the factor being discussed was the operating parameter of the gaging element. But it must be remembered that often two or more of these factors are present simultaneously, and that while one is the operating parameter, the other is a source of instability and error.

For example, in the simple moving-contact element em- ploying a slide-wire (Fig. 64D) the resistance between the moving contact and either end of the slide-wire depends upon *both* the position of the contact and the resistance per unit length of the wire. Change in temperature will affect the resistivity of the wire, and will also change its length— and, if the material of which the unit is constructed is not carefully selected, the actual position of the moving contact can even be changed because of the differential expansion of the different parts of the pick-up. Any of these changes can be a source of instability and of error.

If a suitable electric circuit is selected the largest of these—the change in resistance of the slide-wire—can be entirely eliminated. If an electric circuit employing the potentiometer principle (as in Fig. 80) is employed, the measurement becomes one of the ratio of the resistances of the two portions of the slide-wire, and the actual resistance values are of little consequence. A resistance-ratio element may well be used in a bridge circuit and, if the ratio of the resistances is never far from unity, it should be so used. Errors from temperature changes in the primary element are also eliminated by the bridge circuit. Errors from ex- pansion of the various parts of the instrument can be mini- mized by careful selection and proportioning of materials.

Error and instability are often caused also by variation in resistance of the contact between slide-wire and movable contactor. Through the use of an indicating instrument drawing little or no current (a high-resistance voltmeter or a potentiometer) this source of error may be eliminated.

With carbon-pile and similar devices, another source of trouble appears: these pick-ups often carry currents heavy enough to cause self-heating of the elements. Such self- heating is usually a short-time phenomenon, and may be highly localized. There is little that can be done to counter- act such effects; they must simply be avoided either by keeping the operating current low, or by using another type of resistance element. In any element which depends for its variation in resistance upon either variable-area or variable- pressure effects between parts, instability may be expected.

Primary elements of the tapped-resistor form are inher- ently quite stable; since their indications depend upon the mechanical spacing of the contacts the only effect of tem- perature change is to cause a small change in dimension. This change is usually small enough to be neglected, or it can be corrected by a calibration factor. Changes in re- sistance value do not introduce error in these elements.

Thermosensitive elements are perhaps more subject to extraneous phenomena than any others. Since their re- sistance is a function of their temperature, *any* factor which changes the temperature of an element can (and will) change its resistance as well. If it is desired to measure temperature changes, this is an excellent characteristic, but for other measurements it becomes a source of error.

The filamentary resistance elements employed in most thermosensitive units are subject to mechanical disturb- ances, too. Vibration can cause cooling, because of the in- creased circulation of gas around the filament. Vibration in a magnetic field will induce currents within the filament, which can disturb the electric circuit. At pressures near atmospheric, and with the fine filaments employed in most such units, neither of these effects gives much trouble. More fundamental difficulties require closer attention than these.

Considering gaging elements of the form shown in Fig. 69, it is apparent that the resistance of the thermo-sensitive filaments will be affected by several factors—the gas pres- sure, the current flowing, the thermal conductance of the gas (its composition), the length of the conduction path, and the ambient temperature—all the factors which affect the temperature of the filament. It is not difficult to main- tain the current and the gas pressure constant, while the length of the thermal conduction path depends upon the geometry of the unit; the device can then detect differences in the composition of the gas in the two bulbs. (Or, if the gas is flowing through one bulb, its velocity.) Difference in pressure may be measured by allowing the same gas to flow into the two bulbs, with the pressure in one kept constant. The ambient temperature, however, cannot always be con- trolled. It is customary for this reason to operate the fila- ments at temperatures from 200°C. to 1000°C. above the ambient level, so that changes of a few degrees in the am- bient temperature will produce only minor changes in the flow of heat from the filaments to the atmosphere, other things being equal.

In the hot-wire seismometer and the hot-wire microphone the measurement is one of velocity: it is desired that the rate of heat flow from the heated filament be proportional to some function of the velocity of the gas within which it is placed. It therefore is necessary to shield these units from stray breezes, but not from the acoustic waves being meas-

In the thermosensitive devices used for measurements of ured. The converse is true of the hot-wire anemometer.

In some of the flowmeters employing thermosensitive units attempts have been made to reduce errors from am- bient temperature changes by special means. One of the most effective employs two platinum grids, both in the path of the gas flow, both heated by electric current. Both are cooled by the flow of gas, but the "upstream" one more than the "downstream" one, since some heat is imparted to the flowing gas by each of the grids.[210]

mechanical movements, the rate of heat transfer from one element to another (or to the atmosphere) depends upon the mechanical spacing of the elements. Since there is an inevi- table loss of heat from every heated surface to the atmos- phere, it is necessary to incorporate an entire bridge circuit in the gaging head, if errors are to be kept to the minimum.

The greatest danger of error from instability occurs with strain-sensitive or pressure-sensitive resistance elements, because of their low intrinsic sensitivity. Since it is quite possible for a change in temperature to cause a change in the resistance of an element, comparable to that caused by the unknown magnitude, temperature compensation is essen-

(Continued on page 38)

(210) Marcel Golay. Differential Hot-Wire Gaseous Flow Meter. *Review of Scientific Instruments*, Vol. 9, 1938, pages 55-57.

ELECTRON TUBES—Their Principles and Their Instrumentation Applications

By ANDREW W. KRAMER, Managing Editor, *Power Plant Engineering*, Chicago, Ill.

XXXI. LIGHT-BEAM LINKAGES

(Continued)

The "Hole-in-meter" Principle

This method is based upon the simple expedient of boring a small hole in a voltmeter or any other indicating instrument at a point in the scale where some control function is to come into play and then mounting a phototube behind the hole so that the pointer will intercept a beam of light passing through the hole into the phototube.

As has already been pointed out, most control functions are really extensions of the field of measurement. Any measuring instrument such as a voltmeter or ammeter or thermometer can act as a controller if it can be made to exert sufficient torque to move the mechanism. For example, if the voltmeter connected to the d-c. circuit in Fig. 232 could exert sufficient torque to operate the field rheostat of the small generator through the linkage system shown, it would serve as a voltage regulator as well as a voltmeter. If the voltage of the circuit tends to increase, more resistance will be cut into the shunt field circuit and the terminal voltage of the generator will drop.

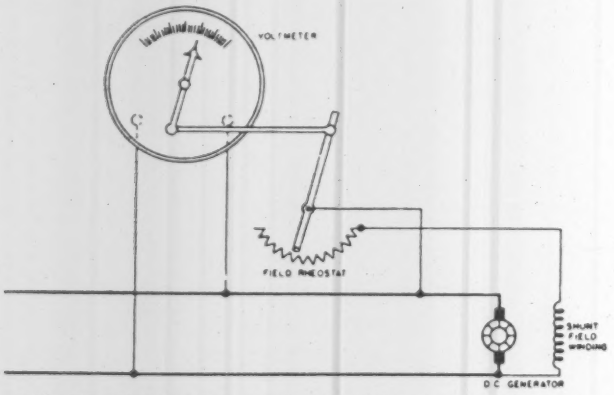


Fig. 232. Showing how a voltmeter might be used as a voltage regulator if it could exert sufficient torque to operate the mechanical system shown.

Where voltage changes are large such a system could be made to work, but of course a standard voltmeter would not be used, as such devices are far too delicate to move any linkage system however delicately constructed. Sometimes measuring instruments are provided with very light contacts which are closed or opened by the movement of the pointer, but beyond that the use of measuring instruments for control purposes is usually not feasible.

This, however, is where the almost inconceivable delicacy of phototube and photocell control comes into play, for, as pointed out in a preceding article, the photoelectric principle permits the use of an imponderable beam of light as a connecting link—not only as a connecting link but as an inertialess, frictionless operating link. By drilling a hole in the scale of an indicating instrument any pointer, however delicately designed or balanced, can be made to intercept a beam of light entering a phototube or photocell. Through suitable vacuum-tube amplifiers the photocell can then in turn be made to actuate controlling elements which will bring the indicating-instrument pointer back to its normal position, and thus, at the same time, restore the normal state of the circuit.

An application of this scheme has been made in the control of a 250-volt d-c. generator. The general idea of this control is shown in Fig. 233. As will be noted, the plate impedance of the final amplifier tube takes the place of the usual field rheostat. This impedance is a function of the grid bias of the tube and this in turn is controlled by the phototube. The latter is mounted behind the hole in the voltmeter so that when the voltmeter needle uncovers the aperture the full illumination falls on the phototube. As the system is arranged, this will cause maximum bias to be applied to the amplifier tube in the generator field circuit and under these conditions the resistance of the generator field circuit will also be at a maximum. The terminal thus will be reduced to its lowest value. On the other hand, when the aperture is covered by the pointer the reverse condition will prevail; the grid bias and the plate resistance of the amplifier tube will be at a minimum and the generator voltage will be at its highest value. The change in voltage permitted will vary between the values represented by the width of the aperture in the voltmeter dial. If the width of the slit represents the distance the pointer moves for a change of 1 volt, the output of the generator will vary ±0.5 volt of the specified value.

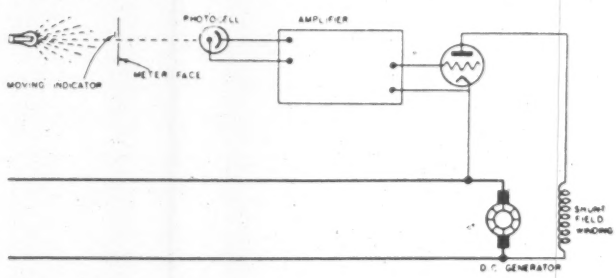


Fig. 233. Basic idea involved in the control of a 250-volt d-c. generator by means of the "hole-in-meter" principle. In this case the final amplifier tube serves as the field rheostat.

Photoelectric Frequency Regulator

A system radically different from this "hole-in-meter" principle but likewise embodying a photoelectric link (this time a "lever") has been utilized in a photoelectric frequency regulator developed by Westinghouse. In this case a frequency meter is the heart of the device, but instead of using the pointer to intercept a beam of light, a small mirror is mounted on the end of the pointer, as shown in Fig. 234. By means of a simple optical system and two sources of light, this mirror reflects light into either of two photocell tubes. When the frequency of the circuit to which the instrument is connected is low, the mirror turns and reflects a beam of light into one phototube; if the frequency is high, the light is reflected into another

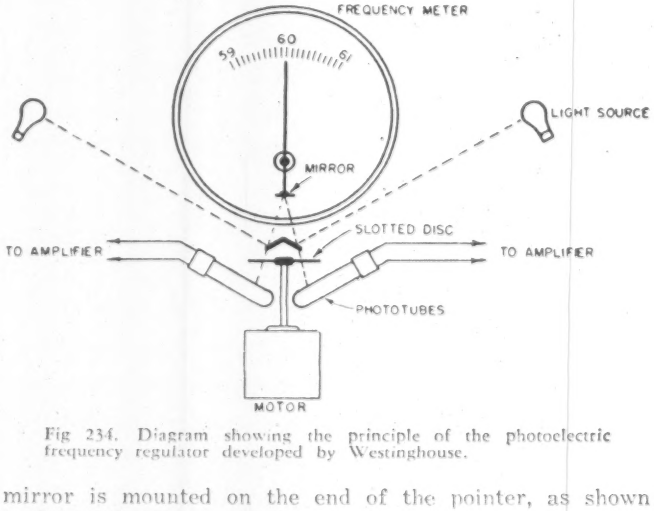


Fig. 234. Diagram showing the principle of the photoelectric frequency regulator developed by Westinghouse.

phototube. In either case the phototube involved will close a relay which will apply proper corrective action to the governor of the prime mover driving the generator. Normally, when the frequency is at the correct value the reflected light from the pointer mirror is intercepted by the fixed mirror mounted immediately below the instrument. Other refinements consist of a slotted rotating disk driven by a small motor to prevent hunting. The speed of this disk is such that the slot lets light through every two seconds. Thus, the phototubes are permitted to apply corrective action for a limited interval of time only. The shape of the slot is such, however, that the greater the deflection of the mirror the longer will be the duration of the corrective action. The system, therefore, brings the frequency back to normal at a *rate* which is roughly proportional to the departure from normal; and the system does not overshoot.

These two applications of the phototube, one in a voltage regulator and the other in a frequency regulator, are presented not so much to describe these particular devices as to indicate how the phototubes and photocells have extended the usefulness of instruments beyond the range of measurement into the field of control. It will be obvious that innumerable adaptations of this scheme are possible. Within this scheme anything that moves a pointer, a column of mercury or water, a rotating disk, etc., becomes a controlling agency.

In the case of the phototube voltage regulator described above, it will be noted that the last amplifier tube must be capable of carrying the entire field current of the generator. This, therefore, limits the application of this system to very small generators, unless some form of grid-controlled gas-filled tube could be substituted for the high-vacuum tubes used. Such tubes are capable of handling much greater power.

The above-described circuits showing the application of the "hole-in-meter" principle all utilize high-vacuum type phototubes. It should scarcely be necessary to point out that the same principle can be used with photocells with excellent results. Where photocells are used, their output usually operates a sensitive relay which in turn controls the power relay controlling the heaters.

Photoelectrically-balanced Potentiometers

Several manufacturers have incorporated the photoelectric principle in automatically balancing potentiometer circuits used in temperature recorders. One of these, the Tagliabue "Celectray" photoelectrically balanced recording potentiometer, is shown in Fig. 235. This circuit uses a thermocouple as the primary temperature-responsive element. The thermocouple and potentiometer circuit is shown at the right while the balancing circuits are shown at the left. Normally, when the temperature remains constant at the setting-point, the light from the lamp is reflected toward the phototube by the mirror galvanometer. In the balance position, the light beam is directed at the edge of the phototube cathode. When the temperature changes, however, the galvanometer mirror swings and this deflects the light away from its balance position. With the light in the balance position, one of the two relays (Nos. 1 and 2) is closed and the other open, and under these conditions the balancing motor is inoperative. When the light beam is off balance, it is either entirely on the photocathode surface or entirely off and the relays are either both open or closed and this drives the motor in one or the opposite direction. When both relays are closed the reversing motor carries the moving contact of the slide wire potentiometer down-scale and when both relays are open, the moving contact travels up-scale.

It should be noted that in the recorder just described the phototube is not a calibrated element but serves only to detect the direction of the light beam and bring the galvanometer to zero deflection in accordance with the well-known null method of balancing an electric circuit. The instrument is therefore not a photoelectric potentiometer; it is a photoelectrically-balanced potentiometer.

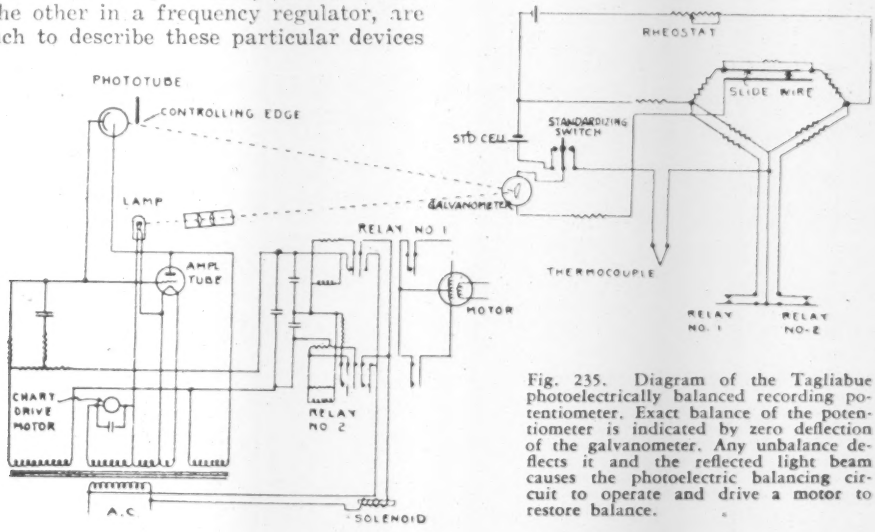


Fig. 235. Diagram of the Tagliabue photoelectrically balanced recording potentiometer. Exact balance of the potentiometer is indicated by zero deflection of the galvanometer. Any unbalance deflects it and the reflected light beam causes the photoelectric balancing circuit to operate and drive a motor to restore balance.

The actual operation of the balancing circuit need not be explained in detail here but a few facts about its operation may be of interest. When the light is deflected away from the balance edge of the phototube it results in a sudden change in the current through the grid resistor in series with the grid capacitor. The change in voltage drop across the resistor is immediately applied to the grid of the amplifier tube, before the voltage across the capacitor changes perceptibly. As the charge on the capacitor changes, however, the grid voltage continues to change in the same direction but at a much slower rate. As a result, the plate current of the amplifier tube increases suddenly to a certain value when the light beam falls on the phototube and then continues to increase to a higher value, but at a slower rate. The initial increase in plate current is adjusted to be between the operating currents of the two relays in series with the plate circuit. This two-step action helps in quick starting of the reversing motor and then prevents it from overshooting the balance point on the potentiometer. If the motor stops before the balance point is reached, the light beam swings back off the phototube and the motor takes small steps until the balance point is reached.

The Photoflash Synchronizer Tester

The capacitor-resistor combination used in the input circuit of the Tagliabue photoelectrically-balanced potentiometer just described also forms the basic principle of an instrument developed for the precise timing of the interval between the closure of a switch and the attainment of greatest brilliancy of a photoflash lamp in the operation of a camera shutter. This device was described by P. A. Marshall of the National Carbon Co. Research Laboratories in the January 1942 issue of *Electronics*. The range cov-

ered by this tester is from 10 to 45 milliseconds. Its basic circuit is shown in Fig. 236A. Operation depends on two gaseous tetrodes which control the charging of a condenser in accordance with the time interval to be measured. In the basic circuit triodes are shown instead of tetrodes for simplicity. Event No. 1, marking the start of the time interval to be measured, exercises control in grid circuit G_1 and causes T_1 to ionize. Capacitor C starts to charge through T_1, but before it is fully charged event No. 2 occurs, marking the end of the time interval to be measured. A pulse of voltage exercises control in grid circuit G_2 ionizing T_2. With T_2 ionized, the plate potential on T_1 is reduced to a value below the extinction potential and T_1 is de-ionized leaving capacitor C with a definite charge, which is a measure of the time interval between events number 1 and 2.

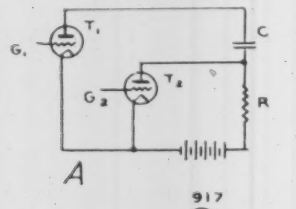
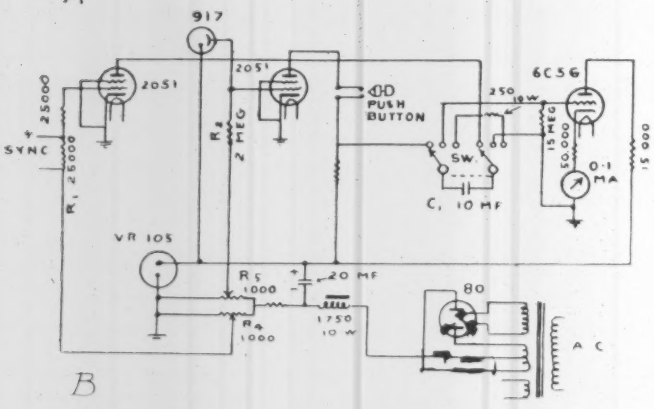


Fig. 236A. Basic circuit of interval timer using two gas tubes and a capacitor.

Fig. 236B. Wiring diagram of instrument, including voltage-regulated power supply.



The actual circuit is shown in Fig. 236B. The photoflash synchronizer under test is connected across R_1 in such a fashion that the voltage of the battery within the synchronizer appears across this resistor as soon as the synchronizer operating switch is closed, ionizing 2051 at the left of the diagram and starting the capacitor charge cycle. A light source such as a 6- or 8-volt automobile headlight lamp is mounted so that illumination from it is directed into the phototube (917). The camera shutter with synchronizer actuator attached is interposed between the light source and the phototube. When the shutter opens, permitting light to fall on the phototube, current flows through R_2 and the voltage developed across this resistor trips the second 2051, extinguishing the first 2051 by virtue of the virtual short circuit across R_3 and stopping the capacitor charge cycle.

The voltage across C_1 is read immediately by rotating switch SW one step clockwise, which connects it to the input of a degenerative vacuum tube voltmeter calibrated directly in milliseconds. After reading the time interval, switch SW is moved one more step clockwise to discharge C_1 and is then returned to the original or charge position after pausing for an instant in the central or "read" position to note whether the indicating instrument returns fully to the index mark denoting a completely discharged capacitor. The pushbutton is then depressed, opening the anode circuit of the second gas tetrode and permitting its grid to regain control. The device is now ready for another time interval measurement.

The instrument is mounted in a portable case with the phototube behind a lens and the light source is contained in another case so that it can be mounted a few feet away. The instrument is self-contained with an 80 rectifier supplying the direct current for the amplifier tubes.

Photoelectric Tester for Camera Shutters

A relatively simple arrangement using a phototube has been used for testing camera shutters. This consisted merely of a phototube followed by a 3-stage direct-coupled amplifier. The output of the final amplifier was connected to an oscillograph element. A 200-watt incandescent lamp served as the source of light and an optical system was arranged to cover the shutter with uniform illumination. The camera lens converged the beam on the photocell. With this arrangement the amount of light reaching the photocell was directly proportional to the amount of shutter opening and the flash of light as the shutter opened and closed gave an oscillograph trace that accurately described the action of the shutter.

General Applications

The instruments and devices described in this article constitute only a few of hundreds of possible applications of phototubes and photocells in providing a means of linking mechanical and electrical systems. The systems described will suggest others. In industrial control, the phototube is used in a wide variety of ways. The bean sorter mentioned is typical of this type of application. Another extremely useful application is in register control in printing. Here the phototube "watches" the edge of the printed pattern and takes care that this pattern registers with the edge of the paper or fabric within narrow limits. In the manufacture of thin sheet steel, phototubes inspect the finished product for pinholes. There are literally thousands of possible applications of this type, many of them quite simple, as those which involve counting of objects as they pass by on a belt conveyor. In such cases the object merely interrupts or reflects a beam of light and thus, through the medium of the photocell and amplifiers, actuates counting mechanisms.

At the present time all phototubes of the emissive type are operated with amplifiers which in turn operate relays. The phototube, inherently, has an extremely high resistance; the resistance of magnetic relays is usually very low in comparison. The amplifier tube serves to match the resistance of the relay to that of the phototube and, at the same time, provides the power necessary to operate relays. At present even the best phototubes are unable to operate relays directly.

Some progress has been made in the development of relays which may be operated directly by the output of phototubes. Rochelle salt crystals, for example, because of their strong piezoelectric characteristics, are mechanically deformed when voltages are placed on their surfaces and relays using this principle have been devised. In other instances electrostatic relays have been devised which, though they require fairly large voltage charges, need practically no current. All of these devices provide attractive future possibilities.

XXXII. CATHODE-RAY ACTION

As had been explained in an earlier article* our earliest electron tubes consisted of a plain cylindrical glass tube with terminals sealed into opposite ends. When these tubes were evacuated, and sufficiently high voltages impressed upon the terminals, a luminous discharge would fill the tube. Among the early discoveries concerning the action of these discharges was the fact that at very low pressures the luminous discharge would disappear and the walls of the cylinder would begin to glow; they were said to fluoresce. It was further discovered that if a solid object was placed in the discharge path, the rays would cast a shadow of the object on the side of the tube away from the negative terminal. This provided the first clue as to the true nature of the discharge, i.e., that the rays consisted of particles proceeding from the negative terminal towards the positive terminal.

Later on it was discovered that if a magnet was held near the tube, the ray, or beam of particles, would be deflected from its normally straight path. The deflection could also be obtained by a pair of electrically charged plates on

*July 1944.

opposite sides of the tubes. In all cases the deflections were in directions which indicated that the rays consisted of negatively charged particles.

It was from these early investigations that the modern cathode-ray tube was developed. The present-day cathode-ray tube is a vacuum tube in which the electrons emitted from a hot filament are first accelerated to give them considerable velocity, then formed into a beam by suitable methods and, finally, allowed to impinge upon a special translucent screen which fluoresces or gives off light at the point where the beam strikes. The beam can be moved laterally or vertically by electrostatic or electromagnetic fields introduced along the path of the beam.

The early tubes also had only cold cathodes, since at that time the principle of thermionic emission was not yet understood. One of the earliest tubes of this kind was the Braun tube, illustrated in Fig. 237. It consists of a tube,

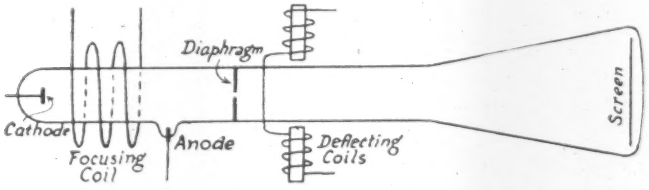


Fig. 237. Braun tube.

cylindrical for about two-thirds of its length but flared out in the final third, as shown. It is about 20" long. A small metal disk, the cathode, is mounted at the narrow end. The anode is a small metal rod projecting into the bulb from the side. Beyond the anode is a diaphragm separating the cathode-anode section from the deflecting-field and fluorescent-screen section. The diaphragm has a centrally located aperture about one millimeter in diameter. The gas pressure in the tube ranges from 4 to 8 microns of mercury. A voltage of 12,000 to 30,000 volts was necessary between the cathode and the anode. When the tube is in operation, the ionized gas molecules bombard the cathode plate causing impact emission of electrons which are accelerated toward the anode by the high positive potential. Because the anode is small and on one side of the tube, many of the electrons travel on past it through the aperture in the diaphragm. This constitutes the cathode ray or electron beam which is deflected by electric or magnetic fields and produces the fluorescent pattern on the screen at the enlarged end. A magnetic solenoid is sometimes placed concentrically over the small end of the tube to assist in focusing the electron beam on the screen.

The Braun tube is not used much at the present time and is described here largely because of its historical interest.

The Dufour Cathode-ray Tube

The Dufour tube* shown in Fig. 238 is similar to the Braun tube in principle but it is a much more highly developed form and is used at the present time in the investigation of very-high-speed transient phenomena. It was developed by Professor Dufour of France.

Like the Braun tube, it employs a cold-cathode source of electrons, but it provides for inserting photographic plates or film inside the tube. The screen end of the tube is usually made of metal with a removable compartment for holding a number of photographic plates. A vacuum pump and pressure gage are part of the operating equipment. About 12 minutes are needed to produce the required vacuum which, in one type, is equivalent to a pressure of 10 microns for a potential of 50,000 to 60,000 volts between cathode and anode. The electrons record by acting directly on the emulsion of the photographic plate or film. A good trace is recorded even when the electron beam sweeps across the film as rapidly as 100 miles per second. As already mentioned, the Dufour type tube, because of the high recording speeds attainable, has proved most useful as a recording oscillograph in the investigation of high-speed transient phenomena. The elaborate equipment needed, however, and its relatively high cost, have limited the use of this type of tube.

*Cathode Ray Tubes and Their Applications. J. M. Stinchfield. *A.I.E.E. Transactions*, Vol. 53, December 1934, page 1608.

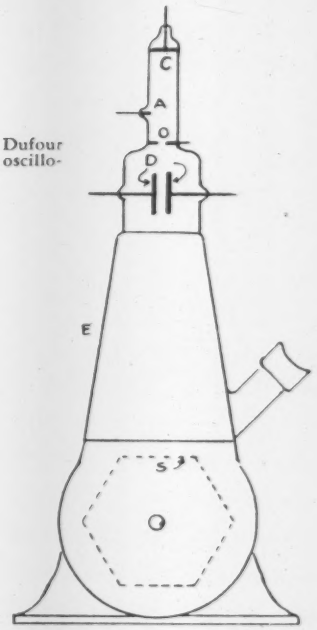


Fig. 238. The Dufour cathode-ray oscillograph.

The Modern Low-voltage Cathode-ray Tube

The principle of the modern low- or medium-voltage cathode-ray tube in universal use at the present time both as an oscilloscope or as a television receiver tube is shown in Fig. 239. It consists fundamentally of a heated cathode emitting electrons, an anode *D* containing an aperture, a set of deflecting plates *P* and a fluorescent screen. The hot

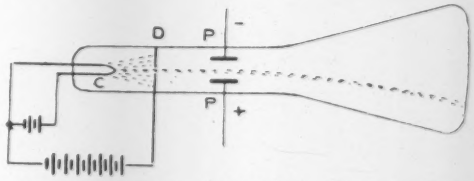


Fig. 239. Illustrating the principle of the low- or medium-voltage cathode-ray tube.

cathode provides a much larger number of electrons than is the case in the cold-cathode type of tube previously described, and, since the emission of electrons from the filament is not dependent upon the anode potential, a smaller accelerating potential can be employed.

A typical low-voltage cathode-ray tube is shown in Fig. 240. Its structure is fundamentally the same as that shown in Fig. 239 but the elements are depicted in greater detail. In some tubes, not much used at present, a small amount of inert gas at low pressure is usually introduced for the purpose of focusing the cathode ray as will be explained below.

From left to right, the elements in the tube consist of a thermionic cathode from which the electrons are emitted, a grid, two cylindrical anodes, two sets of deflecting plates arranged at right angles for vertical and horizontal deflection, and a fluorescent screen. The electrode arrangement, consisting of the cathode, grid and anodes Nos. 1 and 2, is generally referred to as the electron gun and it forms the electrons into a beam. The intensity of the beam is regulated by the grid in the same way as in an ordinary triode or tetrode. A relatively small voltage variation applied to the grid results in large variations in the intensity of the beam. The first anode is a relatively long cylinder with two apertures, as shown. This anode is operated

(Continued on page 32)

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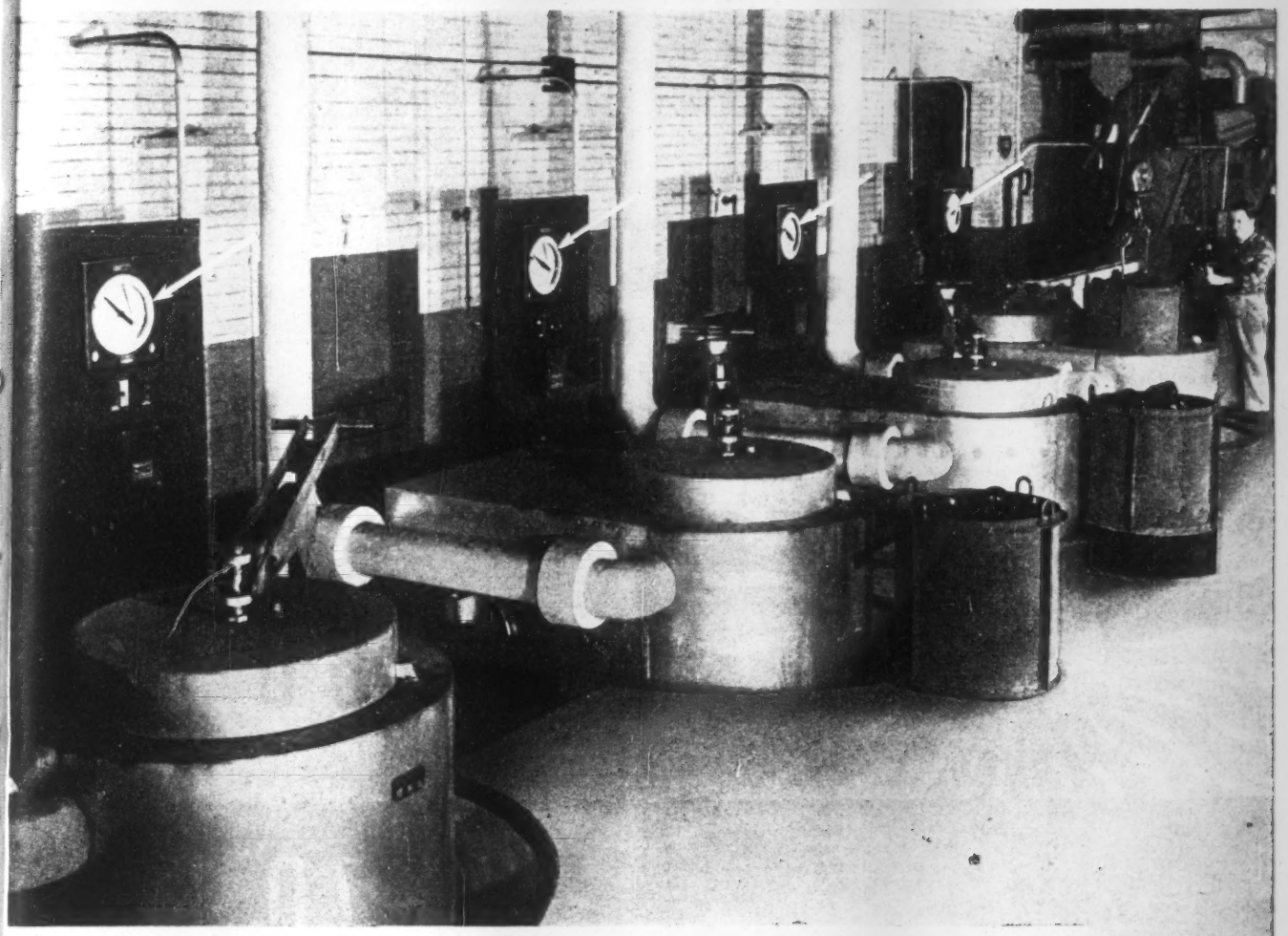

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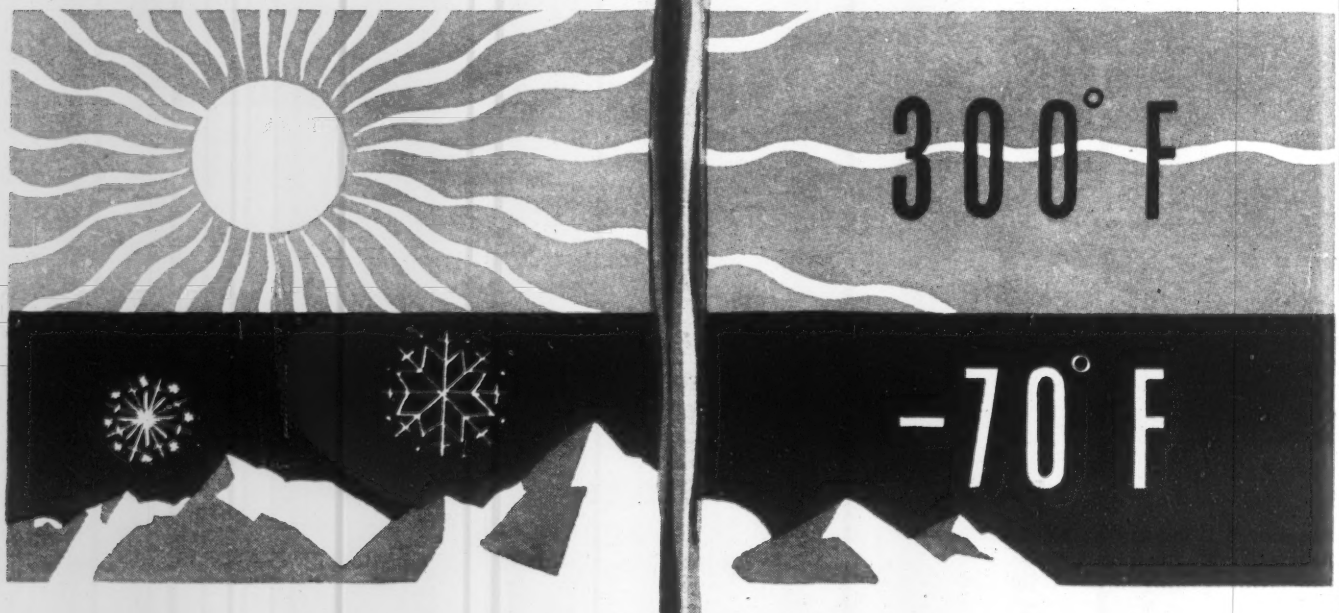

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Vol. IV, No. 1 M. F. Béhar, Editor January 1945

Centralized Gunfire Control of the B-29—a Triumph of Coördinated Computing and Servo Instrumentation

By H. T. HOKANSON (Aviation Division) and T. S. LISBERGER (Aeronautics and Marine Engineering Division), General Electric Co., Schenectady, N. Y.

ALTHOUGH it is not our heaviest armed airplane, the B-29 has been called "the best gunned" airplane. On it are five turrets—two upper, two lower, and one in the tail. These turrets carry 11 or 13 guns. As many as three of these turrets can be controlled and fired simultaneously by a single gunner from a single sight. (Never before has a combat gunner been able to control more than one turret.) More than thirty different combinations of turrets are available to the five B-29 gunners and they can get any one of these combinations in the split-second required to throw the switches.

The upper forward and lower forward turrets are placed ahead of the big propellers. This gives them unrestricted freedom in fighting off attacks in the forward hemisphere. And against those breath-taking head-on nose attacks they team together for concentrated fire power.

The upper rear turret provides protection from overhead attacks; the lower rear from attacks underneath. These two work together in stopping attacks from either side.

The tail turret with its machine guns and cannon, stands guard against offenders from the rear.

All of these turrets are commanded by remote control from five sighting stations. What is "remote-control armament"?

"Remote-control armament" or central-station gunfire control is:

A turret in one place on the airplane and the sighting stations that control it in different and more convenient places in the plane with nothing but electrical connections between the turret and the sight.

A sight pointing at an enemy fighter and the guns pointing to hit that fighter.

A comfortable gunner in a warm cabin at 8,000-foot conditions with his guns in a sub-zero gale at 30,000 feet.

A gunner's undisturbed finger-tip touch on a sight, pushing several heavy machine guns against a 300-m.p.h. wind.

Guns strategically placed, even where a gunner can't be comfortably located.

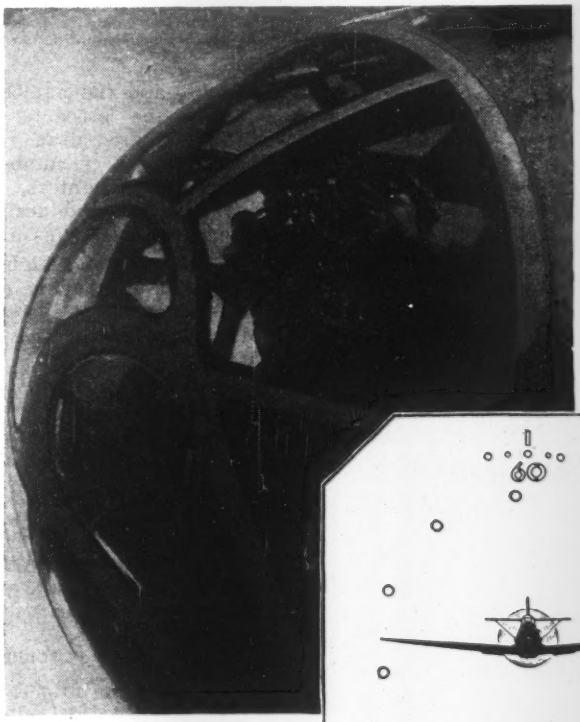


Fig. 1. Nose gunner on the B-29 using one of five sighting stations described in this article. All gunners are inside the comfortable pressurized cabin.

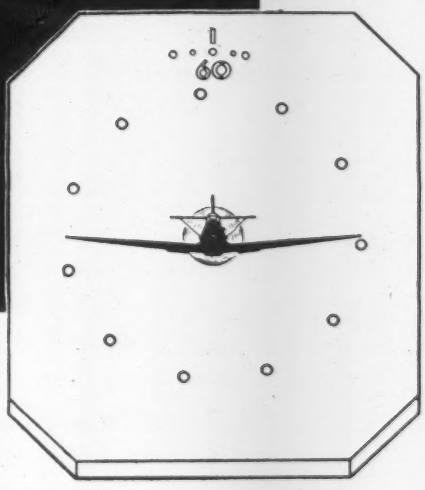


Fig. 2. This is what the B-29 gunner sees through his sight. Tiny spot of light centered on nose of plane is aiming point.

Remote-control armament is not something added—it is engineered into the airplane, it is a part of engineered warfare.

Even before the United States was attacked, the Army Air Forces and General Electric had been developing airplane armament for the future. Engineers were quietly working in laboratories and drafting rooms at Wright Field and at Schenectady to find combinations of electric circuits and mechanical gear which would solve the problems being discovered by the AAF tactical experts. Confidential flight tests of the new armament developments were conducted at guarded AAF flying fields and in aerial solitude over the Gulf of Mexico. When the B-29 was selected for mass production to help win the war against Japan, broad-visioned AAF engineering officers saw that remote-control armament would best fit the new Superfortress and General Electric was requested to design an armament system into the B-29 and to build it.

NEW PROBLEMS

Previously, a military airplane had been built first to fly. Then, if the occasion demanded, guns were added. But long-range thinking by AAF engineers was rapidly establishing a new philosophy—even a new science. The extreme altitude, speed and range of the B-29, together with problems presented by

the new pressurized cabins, made previous armament methods impossible for this airplane. New problems demanded new solutions.

It was obvious from the beginning that the B-29 would have to make long flights to attack Japan. This meant that the gunners had to be kept comfortable in the pressureized cabin (see Fig. 1). But they cannot shoot guns through a pressure-tight wall. The guns must be kept on the outside and must be aimed and fired from inside the pressurized cabin.

The large wind forces exerted against the barrels of machine guns protruding from high-speed airplanes like the B-29 make power drive for these guns imperative. Without this assistance, the gunner could not instantly swing his guns on to a precise aim. The flow of power to drive the guns must be instantaneous in its response to the gunner's command.

The B-29's high altitude, long range and large bomb load is important to fight the Japs. But adequate fire power is also important to fight the Japs. Large formations have been previously used for mutual protection. But experience has shown that "throttle jockeying" by airplanes trying to maintain formation can use enough gasoline to cut their range in half. Adequate fire power and fire-coverage permits operation of small formations or single B-29's. In this way "throttle jockeying" is eliminated and long range results.

Weight and drag are the worst enemies of high-altitude, long-range and large-bomb-load characteristics. But weight and drag increase for every gun added. Therefore enough but not too many guns must be used. The bombing of a Japanese steel mill at Yawata could possibly be accomplished by B-29's with no guns. But if such an attempt were made, the high percentage of losses to Japanese fighter planes would make the mission costly in equipment and human life.

Too large a number of guns is likewise bad. The bomb load must be reduced to pay for the weight of armament. Thus more airplanes will be needed to drop the necessary tons of bombs, and the number of operational losses will increase. Also, the losses to enemy flak will be greater because the increased drag reduces the operational altitude. Even if this large number of guns gave perfect protection from enemy fighters, the other losses would prevent calling this a good design. The optimum design is somewhere between no guns and too many guns.

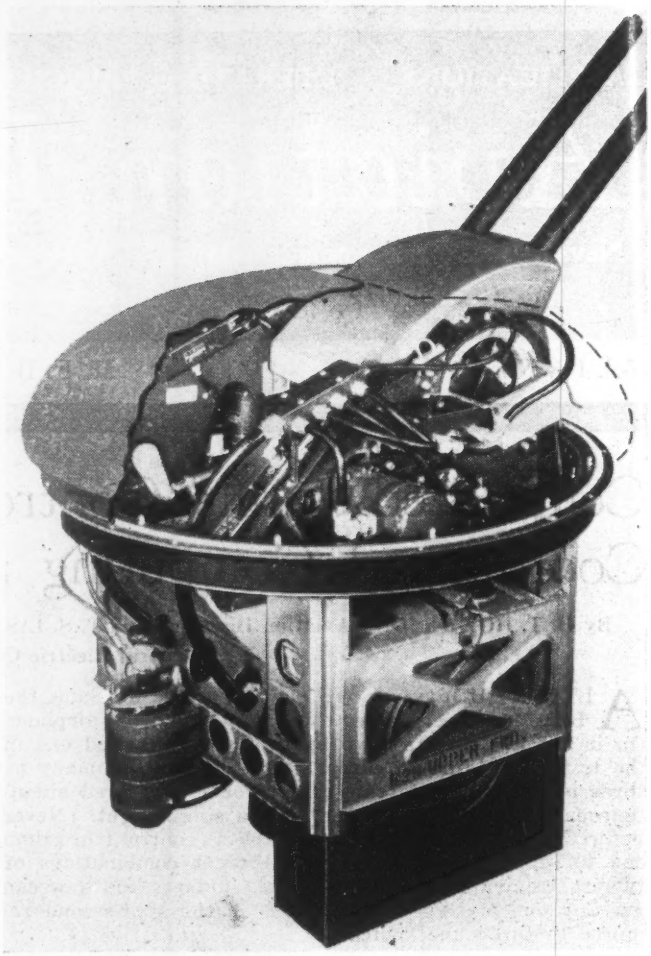
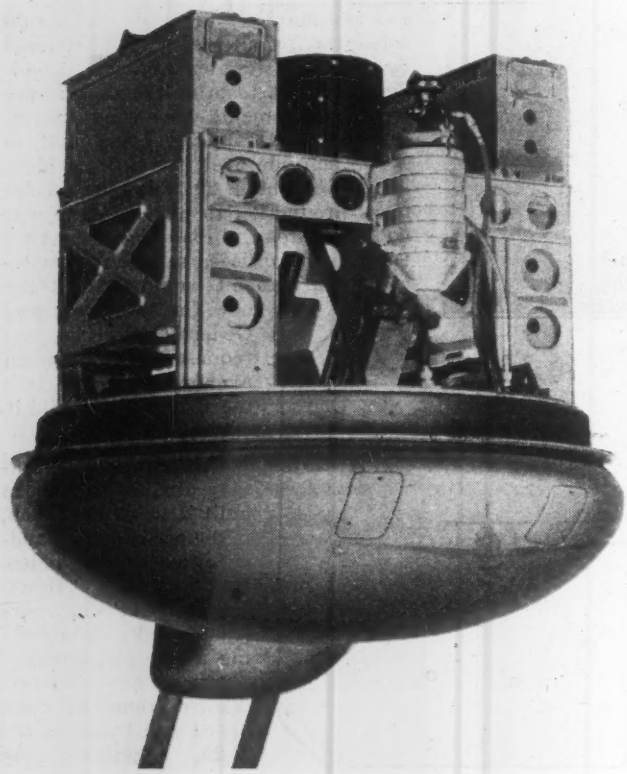


Fig. 3. One of the upper turrets of the B-29 with most of dome shown cut-away to bring out: (a) the compact design of gun-mounts, automatic ammo feed, positioning servomechanisms, etc., (b) the clean aerodynamic design of the low slick dome.

THE FIVE SIGHTING STATIONS AND THE FIVE TURRETS ARE INTERCONNECTED TO FORM AN INTEGRATED SYSTEM WHEREBY EACH GUNNER CAN INSTANTLY TAKE CONTROL OF TWO (IN SOME CASES THREE) TURRETS.

Fig. 4. One of the lower turrets of the B-29.



The high altitude and high speed of the B-29 created new problems in destroying enemy fighters which would attack it. The armament system had to be able to instantly defend the airplane against a variety of attacks greatly different from one another:

(1) Nose attacks in which only three seconds elapse from when the attacking fighter is six blocks away until he is gone behind.

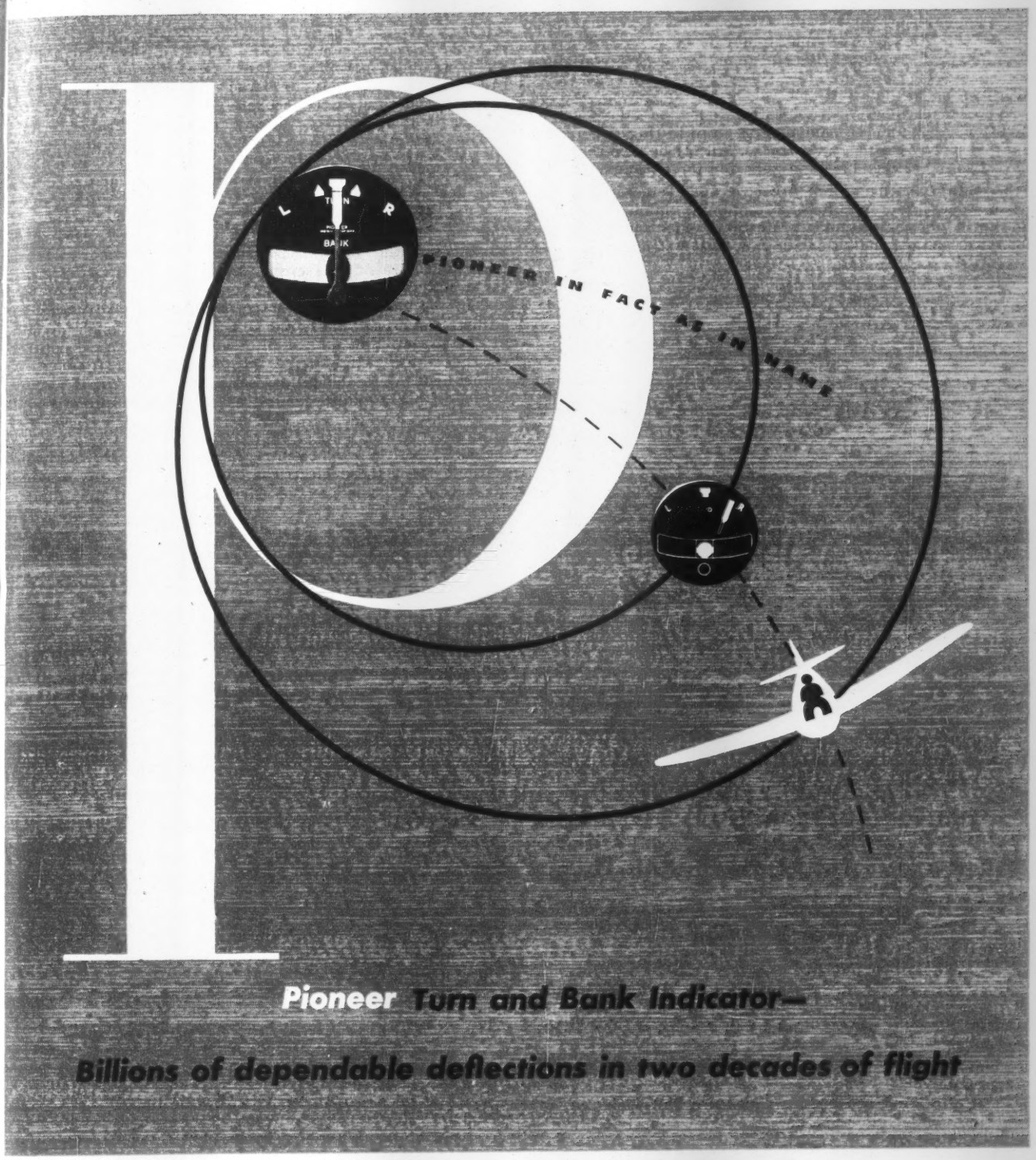
(2) Side attacks in which the relative angular rate is so great that the guns must lead the fighter by as much as 200 yards.

(3) Slowly-closing tail attacks that give the fighter plane a long time to fire, thereby demanding very accurate return fire from the B-29 to win the duel.

Only together could the Army Air Forces, Boeing, and General Electric juggle all of these factors to draw up the requisite specifications.

TURRETS

A good turret is the first essential of a good fire-control system. The turret carries and operates the bomber's guns. Without a good turret, the accessory equipment to control it would become useless and the safety of the airplane would be jeopardized. Each turret had to be provided with enough guns for good hitting power, but not too many guns, because of the weight factor. It was necessary to select the smallest caliber of guns that would



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Teterboro, N. J.

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be lethal against enemy fighters, to permit carrying the most ammunition for the allowable weight. More than two rounds of .50-calibre ammunition can be carried for the weight of one round of 20-mm. ammunition. After all factors had been considered the .50-caliber machine gun was selected for the job with one exception. The Boeing turret was to be provided with .50-caliber machine guns and, in addition, a 20-mm. cannon to give hard-hitting fire power against slowly-closing tail attacks. All other turrets would have two .50-caliber machine guns for the optimum design.

To obtain the maximum fire coverage from each gun in order that there might be a minimum number of guns and still "no-blind-spot" protection, each turret is so mounted on bearings that it can swing around about a

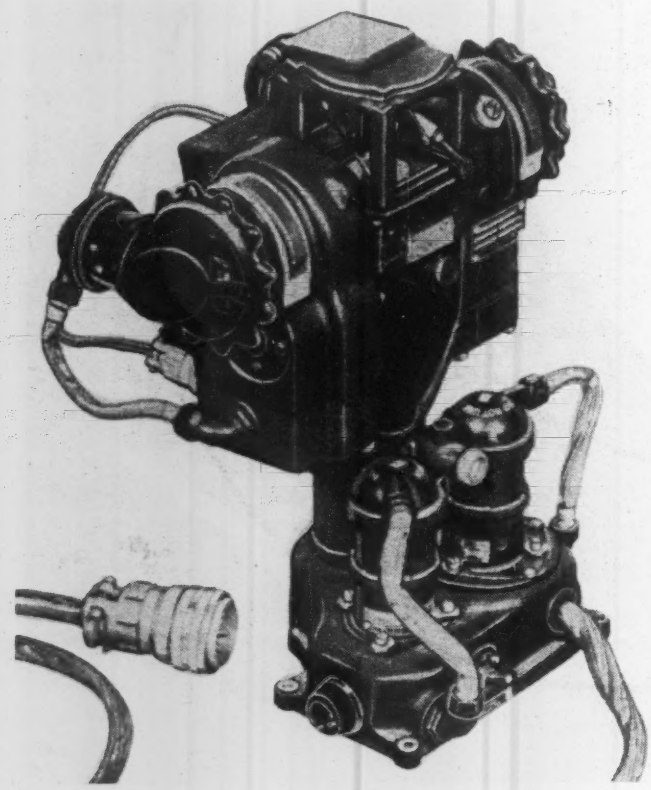


Fig. 5. B-29 sighting station with which the gunner aims and ranges his target and, by means of trigger and knobs requiring no muscular effort, commands the fire-power of one or more turrets.

vertical axis; the guns are fastened to a saddle in the turret that permits them to swing up or down. With this freedom, the guns can be brought to bear in any direction in even more than a hemisphere. (See Figs. 3 and 4.)

Ammunition for the upper and lower turrets is carried in ammunition cans which are a part of the turret. Automatic ammunition boosters are installed for each gun to boost the ammo into the gun. Each gun is provided with an automatic gun charger which performs two functions: (1) It fires the guns by remote control whenever the trigger on the gunner's sight is pressed, and (2) it throws out a bad cartridge and puts in the next one whenever the gun finds one that won't fire—all automatically in a fraction of a second.

Six electric motors are used to operate each turret and point its guns as the gunner aims his sight.

A gunner concentrating on "tracking" a fast-moving enemy airplane might swing the line of fire from his guns through parts of his own airplane. Automatic fire interrupters stop the guns from firing at the gunner's own airplane.

Everything in the turret is built snug and compact. It is finally covered on the outside by a low sleek dome for aerodynamic cleanliness and low drag.

SIGHTING STATION

The sighting station (Fig. 5) used by the gunner to aim at and range the enemy fighter is truly a precision instrument. It must permit a gunner, who has a comfortable grasp on its handles, to "track" a fast-moving enemy fighter smoothly and accurately without stickiness or roughness to disturb his steady touch and throw him off.

The sighting station trigger will fire all guns on all turrets controlled by this particular sighting station.

Mounted on the sighting station is the actual sight. Through it the gunner sees a tiny spot of light which is his aiming point. Whenever he puts this spot on the enemy airplane, he knows that his aim is correct. (See Fig. 2). Around the sighting dot is a circle of other dots of light. The size of this circle can be changed by twisting the range control on his handles. When the gunner has his aiming point on the center of the enemy airplane, he adjusts the size of the circle until it just spans the length of the target. Sun or sky filters and a brightness control on the sighting light give the gunner a wide range of adjustment. With the proper settings, he can sight at any target—from a plane coming at him almost directly out of the sun, to a plane coming at him out of the blackness of night.

Selsyn position indicators are a part of the sighting station; from these electrical connections run to a similar set of Selsyns on the turret. Whenever the gunner

Fig. 6. The B-29 computer connects sighting station and turret, and applies corrections. (Construction cannot yet be disclosed.)

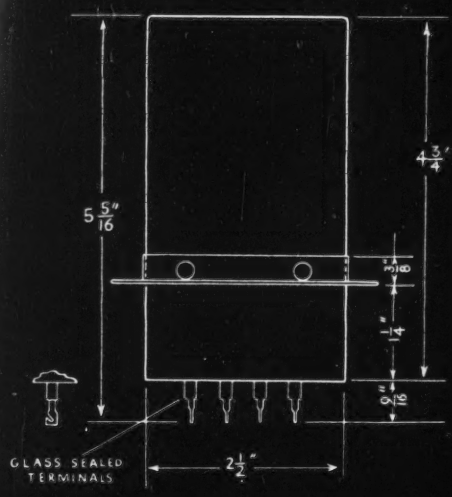
moves the sight, the Selsyns on the sight and the Selsyns on the turret compare automatically the line of sight with the line of fire. If a difference exists, an electrical signal representing the difference between directions is fed into an electronic servo amplifier.

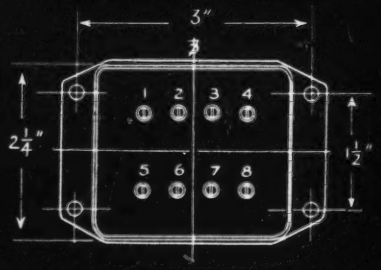
The servo amplifier amplifies the signal it has received and decides which way the guns must be moved to bring them into alignment with the sight. It then applies electric current to the field of an Amplidyne motor-generator, which generates a voltage causing the turret-drive motor to run in the proper direction until the Selsyns signal that the guns are lined up with the sight.

COMPUTER

So far, it has been shown that wherever the sight points, the guns point parallel to the line of sight. But this will not permit hitting the target when the gunner aims at it because:

The guns point parallel to the line of sight. The guns and sights are located a distance away from each other so the guns





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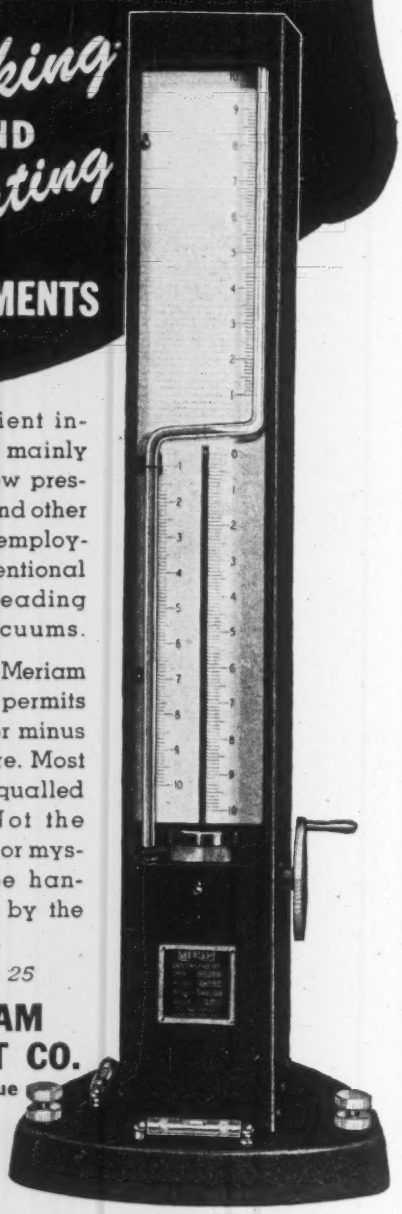

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have to be moved to intersect the line of sight at the target in order to hit. (This is known as correcting for parallax.)

The apparent wind as the B-29 flies along can "blow" the bullets back a whole plane length behind the enemy fighter by the time they get out to him. In order to hit, the guns must be aimed ahead.

Gravity makes the bullets drop. The guns must be elevated to correct for this drop.

The relative motion of an enemy fighter can require lead correction as large as 200 yards ahead of the fighter in the direction he seems to be moving. If a bullet takes a second to travel out to the fighter, he might have moved 200 yards in that time. This must also be corrected for when firing.

The B-29 computer (Fig. 6) was designed to solve these problems automatically and make the guns point to hit the enemy fighter when the gunner aims at him. The computer automatically calculates the parallax, windage, gravity drop, and lead corrections and then adds them together into

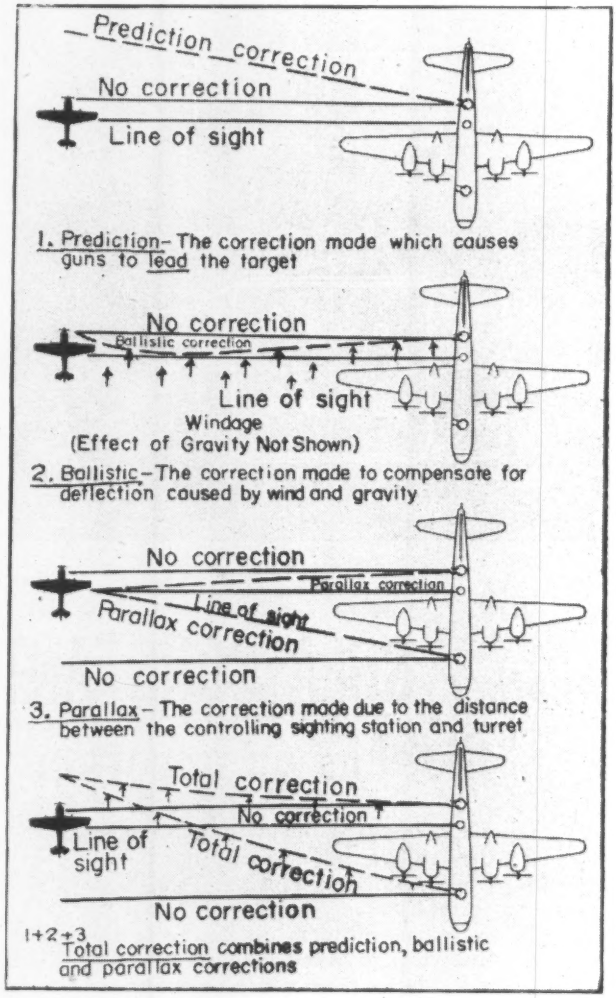
Prediction correction
No correction
Line of sight
1. Prediction- The correction made which causes guns to lead the target
No correction
Ballistic correction
Line of sight
Windage
(Effect of Gravity Not Shown)
2. Ballistic- The correction made to compensate for deflection caused by wind and gravity
No correction
Parallax correction
Line of sight
Parallax correction
No correction
3. Parallax- The correction made due to the distance between the controlling sighting station and turret
Total correction
No correction
Line of sight
Total correction
No correction
1+2+3
Total correction combines prediction, ballistic and parallax corrections

Fig. 7. This is what the automatic computer does in making corrections to hit the target.

a total correction. (See Fig. 7.) This total correction (which might be more than 10°) is superposed on the sight direction signal and causes the turret to point its guns not at the target but so that bullets will hit the target. Thus the gunner can aim right at the target and know that his bullets will hit.

COORDINATION AND INTERLOCKING

Because all sight signals are transmitted electrically, more than one turret can be connected to these signals; so each sight can control as many turrets as are connected to it. Turrets can be transferred from one sight to another by simply operating a switch. In this way, the firepower from all turrets can be distributed for over-all protection or can be concentrated where it is needed the most. B-29 turrets need never be idle regardless of the direction from

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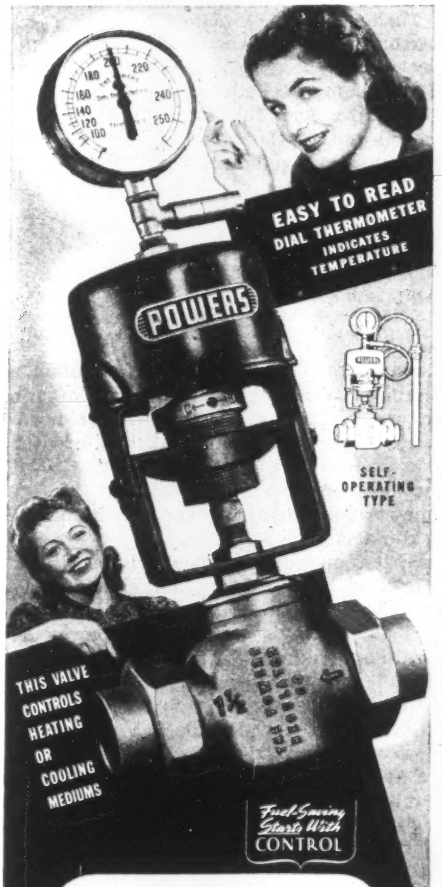

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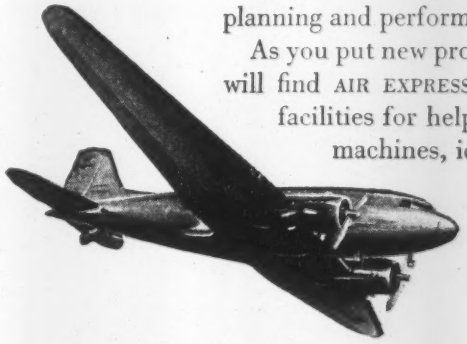

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which the Japs might choose to attack. Fewer turrets can do the job. For these reasons the *five turrets*, the *five sighting stations*, and the accessories are interconnected electrically to form *an integrated armament system:*

The nose gunner controls both the upper forward and the lower forward turrets.

The upper gunner controls the upper rear turret and can simultaneously control the upper forward when the nose gunner is not using it.

The side gunners control the lower rear turret and they can also control the lower forward when the nose gunner is not using it. The side gunners can also control the tail turret if the tail gunner is not using his guns.

The gunners set up these various control combinations with a few toggle switches; and then transfer of turret control between sighting stations is automatic. The combination of control that is selected depends upon the current enemy tactics being encountered, whether the B-29 is in formation or alone, whether it is day or night, and other factors.

Great system flexibility exists because all of the interconnections are electrical. Changes in the armament system arrangement can be more easily made as enemy tactics change. This permits the fullest utilization of the weight carried and minimizes the chances for the enemy to make the B-29 armament system obsolete overnight by changes in his tactics.

The Norden Bombsight

[This is the eagerly-awaited War Dep't. release describing the principal features of what WAS the world's most ingenious aviation instrument; now, in 1945, our planes carry even more wondrous devices.—ED.]

TAKE a set of complicated mathematical formulae, add a dash of mechanical wizardry, put the two in a box no larger than an overnight bag, stick it in the nose of an airplane and you have a weapon that has created a tradition in this war.

The weapon: the fabulous Norden bombsight.

The tradition: that American air power can hit a pickle barrel with a blockbuster.

The weapon has been one of the most vigilantly safeguarded instruments used by the Army Air Forces and the Navy in this war. The tradition has flowered from the flaming wreckage of the enemy's war-making power as it has been struck again and again with pin-point accuracy.

This bombsight and its working companion, the AAF bombing automatic pilot, are triumphs of American inventive and productive ingenuity, unmatched by the enemy. Capable of great accuracy, the bombsight can be used from a wide range of altitudes and speeds. Since it is essentially an optical instrument, the sight is most effective when visibility is good, but special equipment has enabled its use even when the target is obscured.

Development of today's Norden bombsight has been under way since 1924 when the basic design was invented by C. L. Norden. Originally developed and used by the Naval Air Service, the sight is now employed by both Army and Navy, with current advanced models the product of the combined efforts of the Air Technical Service Command, Dayton, Ohio, the Navy's Bureau of Ordnance, the Norden Company, and other manufacturers who are producing the sight under license.

The sight cannot be looked on as merely a mechanical instrument. It represents a specialized training system and a technique of operation that comes only with sustained practice. An American bomber is an efficient offensive unit because from pilot to tail gunner every crewman's purpose is to get the bombsight over the target.

Minutes before starting the run on a target, the bombardier adjusts the bombsight for the determined speed and altitude. He starts the gyroscope spinning, its axis at right angles to the ground. Looking down through the telescope at this point, the bombardier synchronizes the telescope movement with the apparent ground speed. The dropping angle is automatically set up by the bombsight. Arming his bombs, or preparing fuses for detonation, the bombardier takes control of the ship by means of the automatic pilot attached to the bombsight. Knowing that to keep a straight course longer than 25 seconds will give the enemy flak-perfect range, he must work fast. He manipulates four

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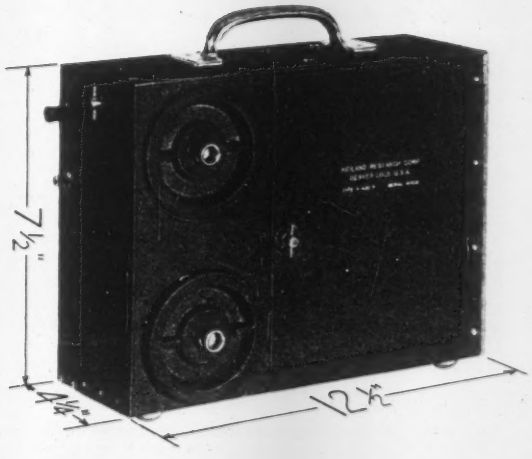

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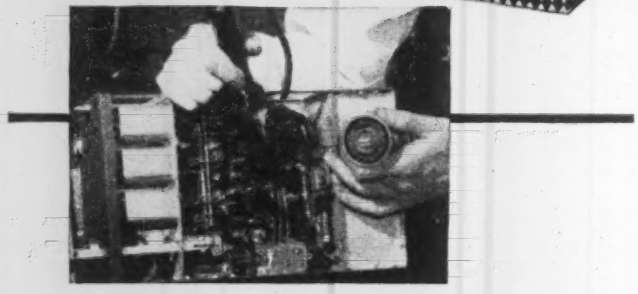

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knobs, two controlling the telescope mechanism and two the course of the plane. When the angle of closure reaches the computed dropping angle he presses an electrical release button, which drops the bombs singly or in train. The bombsight's performance completed, control of the plane passes back to the pilot.

Approximately one minute is required by the bombardier from the time he starts the mechanism of the Norden until the bomb-load goes plummeting down. But that one minute is set in a background of months of training in the use of the device bambardier cadets were once sworn to guard with their lives. Now that the U. S. bombardier is also a navigator, he must go through eighteen weeks of study

Norden Bombsight Revealed. With the publishing of this first picture, taken at the U. S. Army Tactical Center in Orlando, Fla., the cover of secrecy is lifted from the Norden bombsight, America's unparalleled aerial weapon. Bombsights have been captured intact by Germany, but would require years to reproduce.

and practical experience before he can handle the bombsight confidently and accurately in that vital minute. He must have 372 hours of ground school work alone, covering aspects of bombing from maintenance and calibration of the Norden to operation of the automatic pilot. He must spend 25 hours in a bombing trainer, a synthetic device that reproduces flight conditions without leaving the ground. After that begins air training, day and night practice bombing, target identification, and other facets of bombardment adding up to 85 hours. When he wins his wings he is a specialist in aerial destruction, and the Norden bombsight is as familiar to him as a microscope is to a biologist.

Development of the present auto-pilot began in 1938 from original Navy models of what was known as Stabilized Bombing Approach Equipment (SBAE). Research and testing was extensive and continuous, with engineers of the Air Technical Service Command and Minneapolis-Honeywell Regulator Co. carrying out the work under direction of Brigadier General Franklin O. Carroll, Chief of ATSC's Engineering Division, and Colonel Robert J. Jarmon, Chief of the Armament Laboratory.

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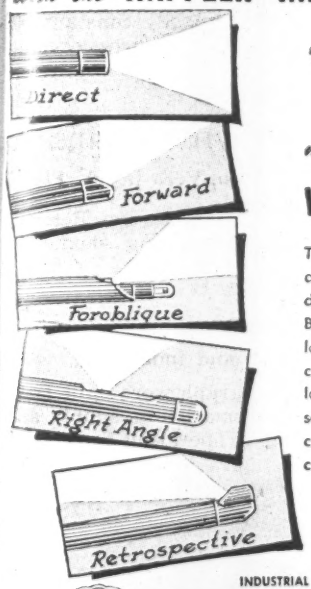

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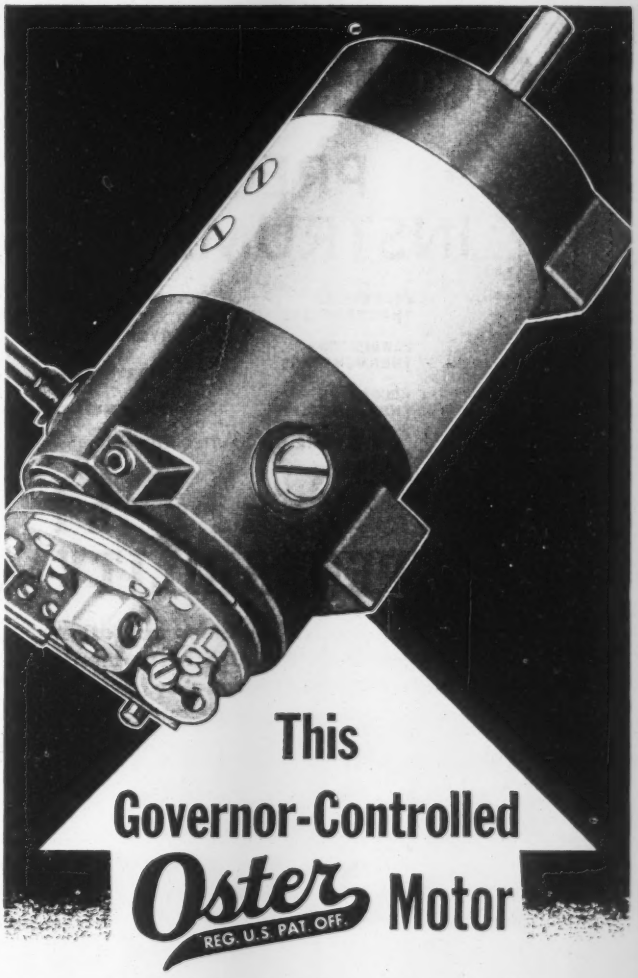

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pilot by AAF flying crews. It gives the bombardier a steady platform for sighting; it holds the bomber on a straight, unerring course during runs; and it relieves fatigue by spelling the human pilots whenever desired. Through its operating efficiency and separate control system, the A-1 auto-pilot has many times been able to bring bombers safely back to base after part of their main controls were shot out of action.

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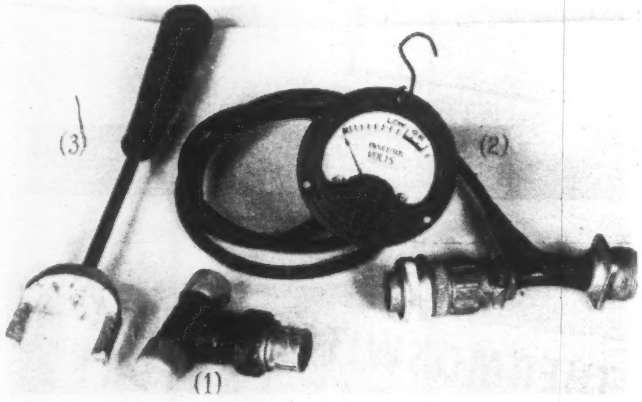
Line Tests on Magnesyn Systems

By M. J. WIGGINS, USN Air Station, Vero Beach, Fla.

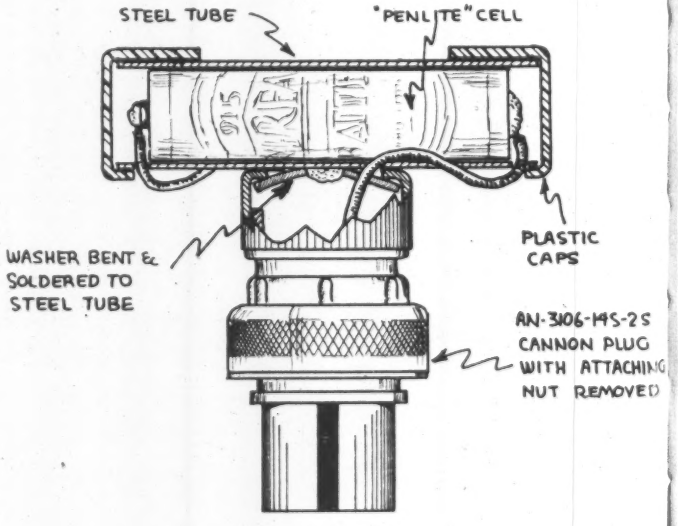
TO obtain an accurate check on a Magnesyn Remote-indicating Compass System the following should be known:

(1) Zero setting of indicators,
(2) Inverter output, and
(3) Friction error of transmitter and indicators.

The three units shown in the photograph were built from available material to obtain this information as simply and quickly as possible under heavy flight operating conditions.



(1) The first point, zero-setting, is checked with the unit which resembles a Cannon plug. Its construction is shown in the sectional drawing: it consists of a 4-prong Cannon plug with a steel tube attached to form a tee. This tube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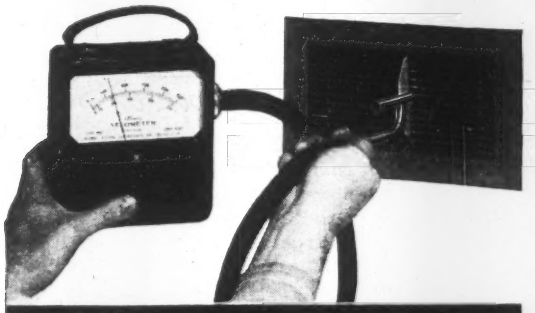
PLASTIC CAPS
AN-3106-14S-2S CANNON PLUG WITH ATTACHING NUT REMOVED

serves as a handle and as a holder for the "penlite" cell which furnishes the necessary voltage. The tube is capped on each end with small plastic caps such as come on new aircraft spark plugs. In use, this unit is plugged into an



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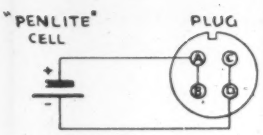
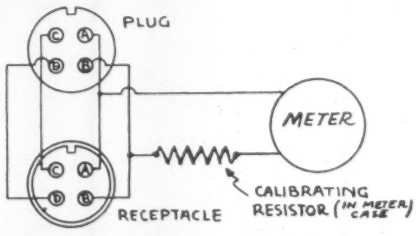


ZERO-SET HOOK-UP

indicator, which should read exactly "North." If the indicator reads off, it should be replaced as this error would appear on all headings.

(2) To determine the inverter output under full load, the tester shown is built from a salvaged a-c. voltmeter of the repulsion-vane type. The voltmeter was originally used in 800-cycle aircraft radio-power supply and had a 120-volt range. The series resistor is removed and a lower-value resistor substituted to obtain a full-scale deflection of about 30 volts. The dial is then marked with an "OK" sector at



INVERTER VOLTAGE TEST HOOK-UP

26 volts ± 10% at 400 cycles. (For 52-volt 800-cycle compass system, mark accordingly.) The voltmeter is then fitted with a lead cord which is attached to a male and female Cannon connector as shown in the diagram.

For an inverter test in the plane, remove the Cannon plug from the compass indicator and attach it to the male connector of the test voltmeter. The female plug is then connected to the indicator. Turning on the inverter will give a reading on the test voltmeter, this reading being the inverter output under full load. If the reading is out of the tolerance limits, replace or repair the inverter.

(3) Friction error and general operation of the system can be checked with a permanent magnet. The magnet shown at the left in the photograph was removed from a salvaged Selsyn fuel quantity transmitter assembly and fitted with a file handle. By moving the magnet around the transmitter, the operation of the indicator may be observed. Upon removal of the magnet the indicator should return to the original heading. The amount the indicator is off from the original heading is an indication of the friction error and should be within the limits of the current Technical Orders. Some *indicators* can be displaced (with power off) with the magnet by rotating the magnet about the face of the indicator. When power is applied, any friction error apparent will then be in the indicator alone.

ELECTRON TUBE PRINCIPLES

Continued from page 15

at a positive potential with respect to the cathode, thus accelerating the electrons which pass through the grid. On emerging from the second aperture in the first grid, the electrons are traveling in practically parallel straight-line paths. The electrostatic fields set up by the potentials on anodes Nos. 1 and 2 form an electron lens system, comparable to an optical lens, which makes the electron paths converge to a point at the fluorescent screen in much the same way that a glass lens bends parallel rays of light to a point focus. Focusing of the electron beam is accomplished by varying the potentials on the anodes, the potentials in turn determining the strength of the electrostatic fields. In practice, the potential on the second anode is usually fixed while that on the first anode is varied to bring the beam to a focus. For this reason the first anode is usually called the focusing electrode. In some tubes a second grid is introduced between the control grid and the first anode to provide additional acceleration of the elec-

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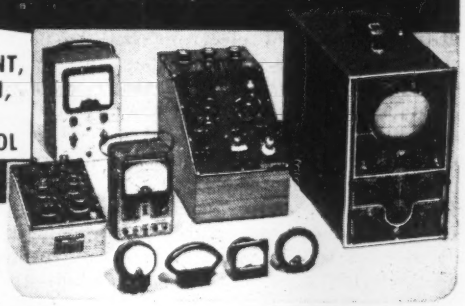

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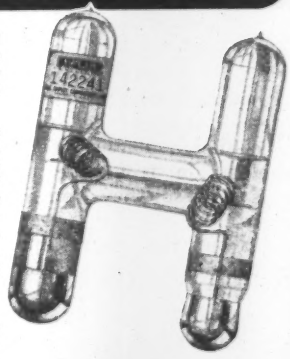

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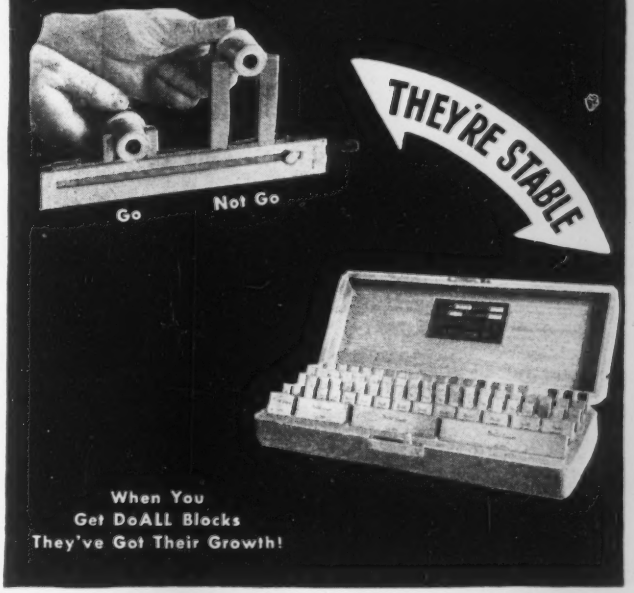

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trons. Sharpest focus is obtained when the electrons have high velocity; for this reason relatively high potentials are common. The currents to the anodes are very small, however, usually not over a few milliamperes, so the power required is negligible.

With zero potential on the deflecting electrodes and, when properly focused, the beam from the gun simply produces a luminous spot at the center of the fluorescent screen. If a potential is applied to either or both sets of deflecting plates, the beam of electrons will be bent and the luminous spot will move to some other point on the screen. If the potential on the deflecting plates is varied rhythmically at a rapid rate, persistence of vision will make the moving spot appear as a line, straight or curved, depending upon the relative strength and phase displacements of the potentials on the electrodes.

In use, one plate of each pair is usually connected to the second anode to establish the polarities of the field with respect to the beam and to each other.

Cathode-ray tubes intended for magnetic deflections are similar to the one shown in Fig. 240 except that the deflecting plates are omitted. Instead, the deflecting fields are set up by means of electromagnets. The magnets are external to the glass envelope but are mounted as close to the tube as possible and in the same relative positions occupied by the electrostatic deflecting plates. Four magnets are ordinarily used, two sets at right angles with their axes running through the center of the tube.

The amount of the electron beam is deflected by a given change in field intensity is called the "deflection sensitivity" of the tube. With electrostatic deflection it is usually expressed in millimeters per volt, which gives the linear

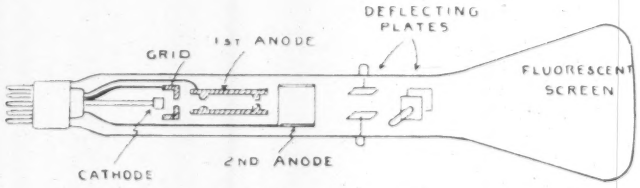
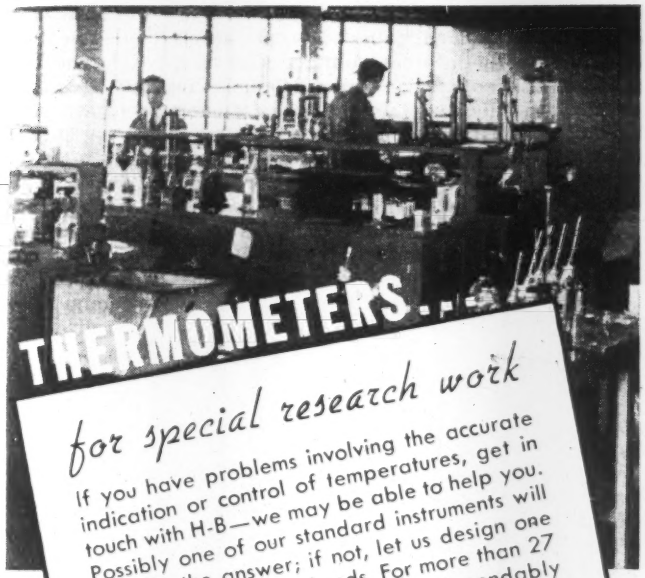


Fig. 240. A typical low-voltage cathode-ray tube.

movement of the spot on the screen as a function of the voltage applied to a set of deflecting plates. Values range from about 0.1 to 0.6 mm. per volt, depending upon the tube construction and the gun electrode voltage.

Principle of Gas Focusing

Mention has been made of gas focusing. This method is not used very much in present-day tubes because focusing problems have been overcome by proper electron gun design; the method, however, is of interest. In gas focusing, argon gas at pressures of 10^{-2} to 10^{-3} mm, of mercury is introduced into the tube. This gas serves two functions: first, the positive ions produced by the electrons moving through the gas neutralize the negative charges that tend to accumulate on the tube walls and might produce undesired deflections of the electron beam. Secondly, it serves to focus the electron beam in the following manner: As the electrons move toward the fluorescent screen, some of the atoms lying in the path are ionized by collision. The positive ions so produced receive little acceleration from the impact by reason of their great mass and so they remain relatively stationary with the beam. The electrons produced by the collisions drift radially outward very rapidly because of their light mass. As a consequence, a column of positive ions extends down the length of the tube and this produces a radial electric field, the direction of which is such as to direct the electrons tending to stray away from the center of the beam inward toward the axis. This offsets the natural repulsion of the electrons for one another and produces a sharp, well-defined spot on the fluorescent screen. The life of gas-filled tubes is short compared to the vacuum type, however. The bombardment of the cathode by the massive positive ions slowly causes it to disintegrate to the point



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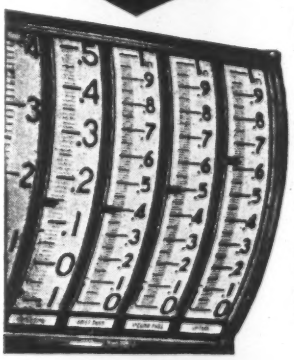

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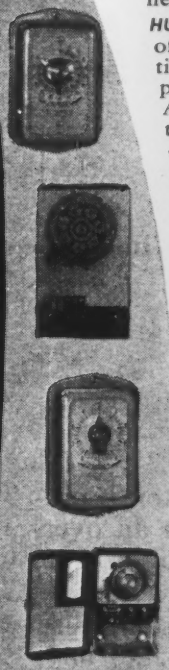

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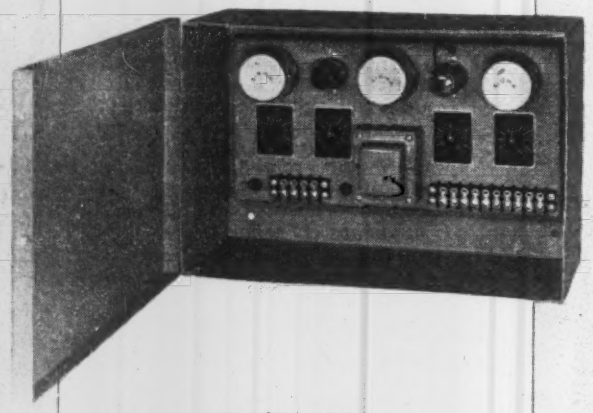

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where its emission falls so low as to render the tube useless. Also, gas-filled tubes present different degrees of sensitivity with different voltages and tend to become unstable during operation from changes in gas pressure. In short, the disadvantages of gas focusing are many and for this reason the method has been almost entirely superseded by the more modern electron gun arrangement previously described.

The operation of the high-vacuum cathode-ray tube gives rise to an accumulation of undesirable negative charges on the inside of the glass envelope which, if they are not symmetrically distributed or removed, may cause spurious deflections of the electron beam. In the high-vacuum tube there are, of course, no positive ions to neutralize the negative charges.

Of course, if the negative charge is uniformly distributed on the inside surface of the tube, the resulting field will be symmetrical and the electron beam will not be deflected. As a matter of fact, such a symmetrical charge aids in focusing the beam since any electron that moves off the beam axis is repelled by the field and will be deflected back to the beam.

The luminosity of the cathode spot is reduced by the repelling action of the surface charge of the screen and for this reason methods have been developed to effect the removal of the surface charges. One method is to coat the inside of the tube with a conducting material such as graphite and then electrically connecting this conducting surface with the second anode. Sometimes the second anode itself is dispensed with and the conducting surface on the inside of the tube used as the final accelerating electrode.

Cathode-ray Tube Circuits

The electrical connections for a cathode-ray tube are shown in Fig. 241. One plate of each pair of deflecting plates is connected to anode No. 2. Because of the high potentials used in the operation of cathode-ray tubes, the

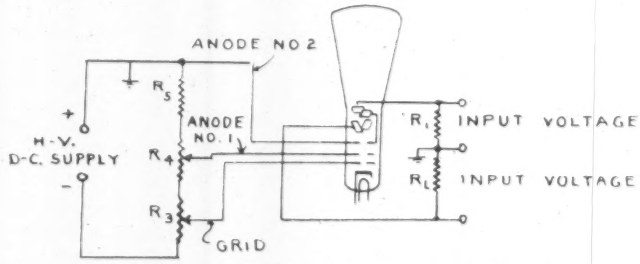
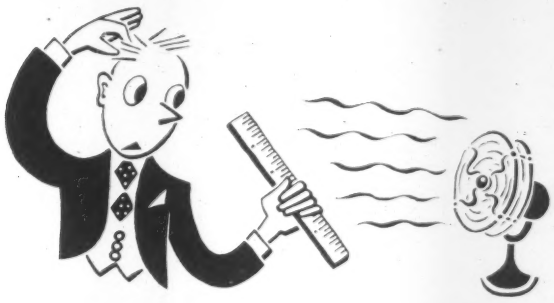


Fig. 241. Electrical connections for a cathode-ray tube.

positive terminal of the direct-current supply is usually grounded. This places the common deflecting plates at ground potential. As a consequence of this method of connection, the cathode and other elements are at high potentials above ground; hence, these electrodes must be well insulated. The required d-c. voltages are obtained from a voltage divider across the high-voltage d-c. supply as shown. The negative bias on the control grid is adjusted by voltage-dividing resistor R_3. This, as already explained, varies the beam current and hence the intensity or brightness of the cathode spot. It is called the intensity or brightness control. Voltage-dividing resistor R_4 which changes the ratio of the voltages on anodes Nos. 2 and 1 regulates the focus of the beam and therefore the sharpness of the cathode spot. To a certain extent, the focusing and intensity controls are interlocked—variation of one affects the other slightly. Sharpest focus is obtained when the beam current is low.

The input voltages for the two sets of deflecting plates are applied across resistances R_1 and R_2 which, usually, are of the order of a megohm or higher. Their purpose is to drain off any accumulation of charge on the deflecting plates. Provision is often made for placing an adjustable d-c. voltage on each set of deflecting plates so that the spot can be centered when stray electrostatic or magnetic fields are present. The adjustable voltages simply neutralize such fields.



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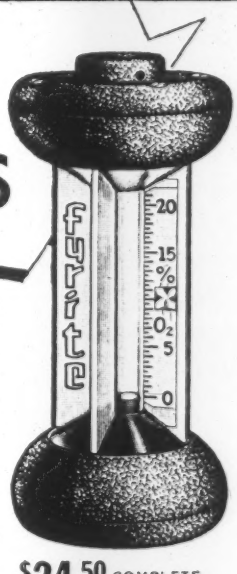

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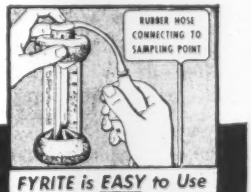

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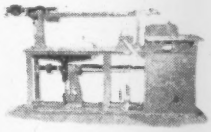

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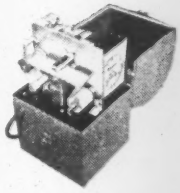

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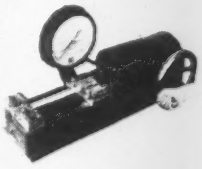

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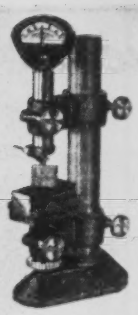

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Continued from page 11

tial. Systems of this kind should employ resistance-ratio elements—it is advisable occasionally to incorporate all four arms of a bridge circuit in the pick-up head. If the initial resistances of all the arms of the bridge circuit are made equal, and if they are all made of the same material, a high degree of temperature compensation will result. It is essential that their mechanical mountings be made similar; otherwise differential thermal strains will affect the several arms of the circuit, and the compensation will be impaired.

Most strain-sensitive resistance gaging elements are used for measuring strain, or some magnitude which has been converted into a strain. It is necessary, in such a measurement, to provide some satisfactory method of imparting the strain in the specimen to the gage material. In many applications this is accomplished by attaching the gage directly to the specimen with an adhesive material, so that the two are compelled to act mechanically as a single unit. The requirements imposed on the adhesive in such an application are rather severe: it must transmit a shearing force undiminished from specimen to gage, and it must continue to do so over long periods of time despite changes in temperature and humidity. Adhesives have been especially developed for this application, and when they are carefully used they give satisfactory results in most applications.

It is obviously necessary that the electric circuit possess a degree of stability as high as that of the primary element, or higher. The procedures and techniques for obtaining such stability have been treated elsewhere. For convenience in reference, however, two typical circuits for providing constant exciting energy have been given (see Fig. 82); no deflection bridge circuit or series circuit can be more stable or more accurate than its source of exciting energy.

Since the equipment employed in electric gaging practice is often used in circumstances entirely foreign to the laboratory, errors may occur from causes not ordinarily considered. When the different parts of such a circuit are placed at points at which temperature differences occur, thermoelectric currents may be produced which will disturb the balance of a d-c.-excited bridge circuit. With care in selection and arrangement of materials, this may be made a negligible source of error or instability. It must be remembered, however, that such potentials may occur when no difference in composition of material is present (the thermoelastic effect).[211]

Another source of instability and error, peculiar because it is a short-time effect exclusively, is the production of electromotive forces between two dissimilar metals both at the same temperature.[212] This phenomenon is not well understood, but it is known that such electromotive forces are produced by relative motion of the two materials, and that the magnitude of the potentials depends upon the position of the metals in the electromotive series. This effect has been known to cause difficulties in self-balancing systems, especially when subjected to vibration. It, also, is eliminated by careful mechanical design and selection of materials.

The long connecting leads required in some applications provide another source of instability. While their resistance effect can be taken care of, electric currents induced in them if they run through alternating electromagnetic fields sometimes cannot. Under ideal conditions, the presence of a small amount of alternating current in a d-c. bridge circuit need cause no error, excepting due to difficulty in balancing which may obscure the sharpness of the balance. But in the practical circuit it is not uncommon for rectification to take place at points of imperfect contact, and for the resulting direct current to upset entirely the operation of the circuit.

The effects just mentioned require consideration especially in systems employing strain-sensitive elements oper-

(211) F. Lichtenberger, Einwirkung elastischer Spannungen auf die Thermokraefte. *Luftfahrtforschung*, Vol. 14, 1937, pages 26-35.

(212) J. B. Seth, B. Gulata, and S. Singh. Electromotive Forces Between Two Metals in Relative Motion. *Philosophical Magazine*, Vol. 12, 1931, pages 409-429.

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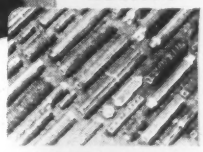

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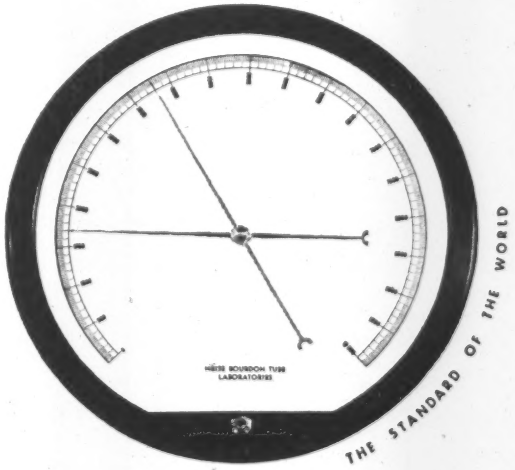

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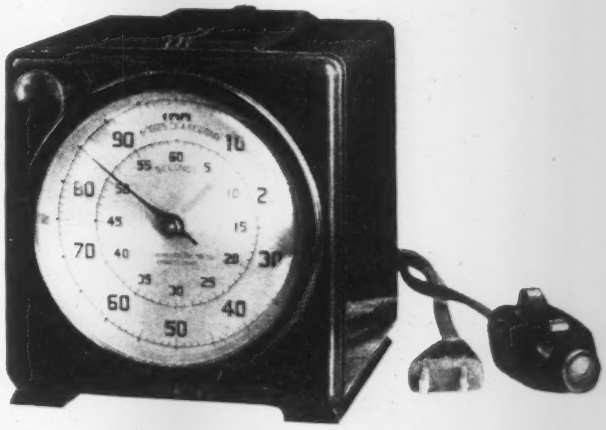

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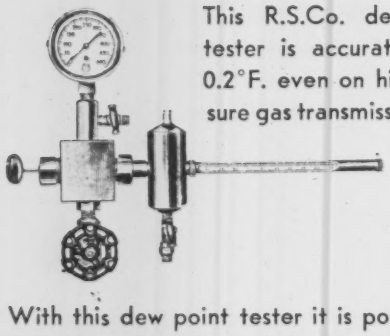

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ating at low levels. With other circuits providing greater outputs, these effects ordinarily are negligible.

§9. Accuracy.

The accuracy of an electric gaging system can never be of a higher degree than its short-time stability; if the sensitivity of the system changes or if its zero drifts during a measurement, error is inevitable. But the *long-time* stability may be poor—that is, there may be a continuous slow change of sensitivity or of zero setting—and yet the accuracy may be high over any particular *short* period. It is only necessary to make frequent checks on zero setting and on sensitivity value and apply suitable corrections as required. Such corrections may be factors noted down to be used in computation, or changes in instrument setting.

Often it is possible to install a gaging system in such a manner as to allow all measurements to be made as differentials; zero drift then may become no more than a source of annoyance.

The percentage accuracy of systems employing moving-contact-gaging elements may be made high, since these elements may be made to provide high output, and thus be freed from the errors caused by small instabilities. Their long-time calibration is usually good. Careful design and construction, with the use of bridge-type or potentiometer-type circuits, and with the primary elements of the resistance-ratio form, will eliminate most of the errors in such a system. It is a most interesting fact that devices of this sort are among our best, and have been for many years.

The accuracy of the Wheatstone, Carey-Foster, Kelvin or other bridge circuit, when used in a null manner, depends upon these factors: the accuracy of the calibrated standards, the sensitivity of the indicating instrument, and the care exercised in operation—which includes the maintenance of the equipment, and especially the connections, to avoid contact troubles. It may be said, then, that the accuracy of these null methods depends primarily upon the standards used, providing always that the indicating instrument is sufficiently sensitive.

It is not especially difficult to attain a sensitivity of one part in one hundred thousand, and an accuracy of one in ten thousand, with a d-c. bridge circuit using a moderately sensitive galvanometer. Such equipment is somewhat slow in operation and subject to disturbance from vibration. It therefore is common practice to employ amplifier systems, so that robust indicating instruments of low current sensitivity may be used. No error is introduced by an amplifier, if a null method is employed, unless the amplifier is so imperfect that it generates and introduces signals of its own.

In some applications, servo-systems are employed to balance the bridge circuits employed with variable-resistance elements. When such a servo-system is adjusted for optimum operation, there is a "dead zone" at the balance point. This dead zone may be made small by careful adjustment of the system. In a well-designed system, the dead zone should not be more than ¼% of the scale range. (The magnitude of the dead zone is a function of the stability of the equipment and the care exercised in adjustment. Its presence is a symptom of imperfection of equipment; there is a dead zone in a manually balanced system, too, but it can be made much smaller by the exercise of the operator's judgment.)

When servo-systems are used to control forces—as in remote-positioning systems—it is convenient to impose a non-linear action upon the system, so that the restoring force increases very rapidly with departure from balance. Through this procedure the speed and the reliability of the system are increased, and usually the accuracy as well.[213]

In any deflection method, the burden of the accuracy requirement is transferred to the indicating or recording instrument, and the source of the exciting energy. (It is assumed that facilities are available for calibrating both circuit and instruments.)

When deflection methods are used for dynamic measure-

(213) W. H. Gille and R. J. Kutzler, Application of Electronics to Aircraft Flight Control. *Transactions American Institute of Electrical Engineers*, Vol. 63, 1944, pages 849-853.

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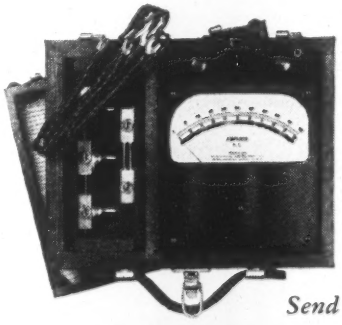

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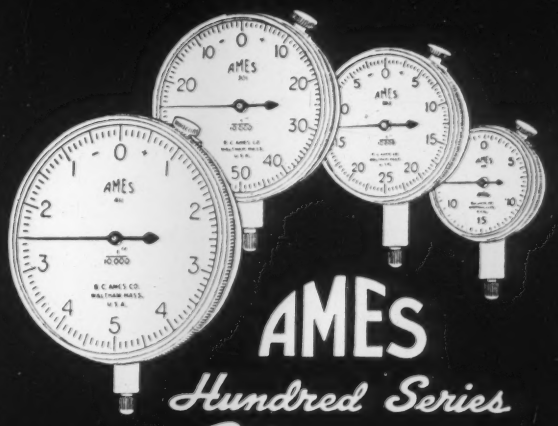

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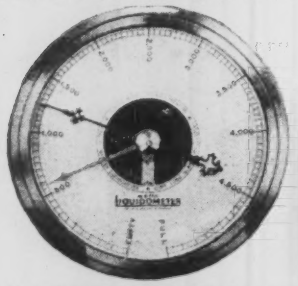

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ments, the current taken by the recording instrument may no longer be small compared to the exciting current. The relation given in Section 6 will no longer accurately describe the behavior of the circuit. If high accuracy is required, it is advisable to perform an experimental calibration, and provision should be available for checking the sensitivity at frequent intervals.

When the current drawn by the indicating or recording instrument is large, special precautions must be taken to insure that the exciting potential remains constant under all conditions. If a regulated supply is used, for example, the regulation must act with sufficient rapidity to accommodate changes produced by the dynamic phenomenon being measured.

Since the resistance variations to be measured are often small—particularly with strain-sensitive primary elements—the problem of making accurate measurements becomes more difficult. Some skill in the operation of such circuits is essential, if continued good results are to be obtained. Irregularities in operation, symptomatic of inaccuracies, may not be recognized by inexperienced operators.

In general, the highest accuracy with a resistance-type gaging circuit is obtained through the use of a bridge circuit having arms of fixed resistance values, an accurately controlled source of exciting potential, and a sensitive potentiometer as an indicating instrument.[214] Extremely high sensitivity, reliability, and accuracy may be secured with such an arrangement, although its operation is rather slow. More rapid operation, without too great sacrifice in accuracy, may be obtained by employing an amplifying indicating system, with a carefully stabilized amplifier and a robust instrument.

To be continued

(214) L. H. Adams, R. W. Garanson, and R. E. Gibson. Construction and Properties of the Manganin Resistance Pressure Gage. *Review of Scientific Instruments*, Vol. 8, 1937, pages 230-235.

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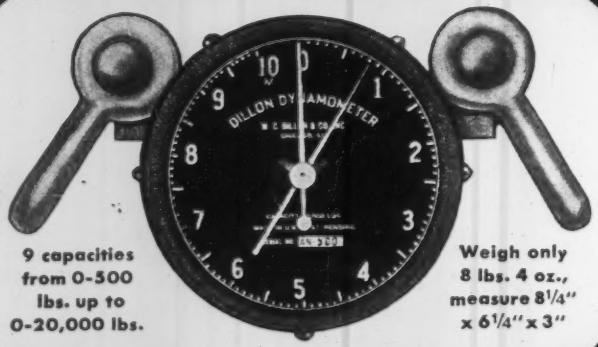

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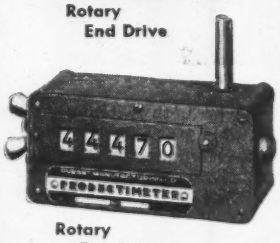

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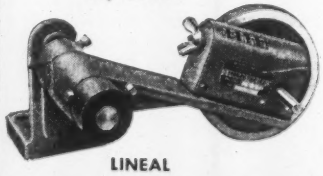

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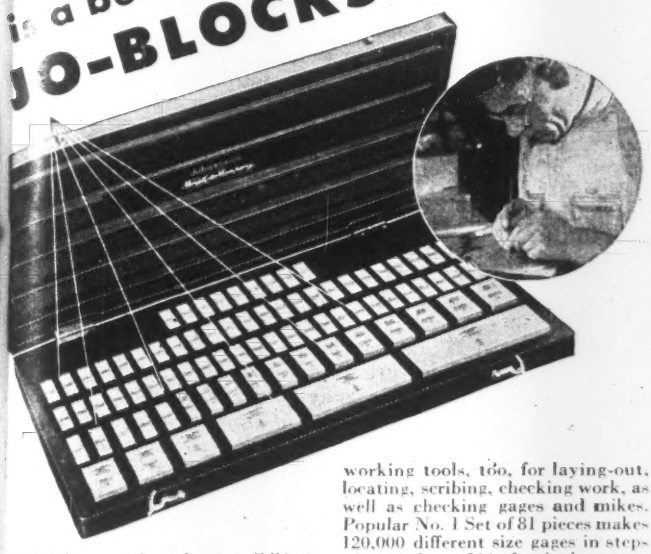

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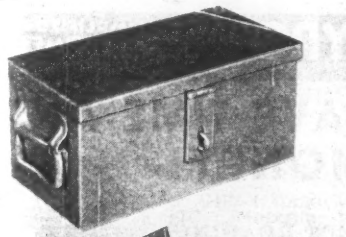

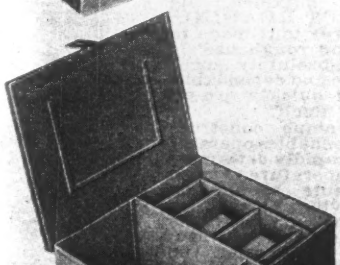

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1025-10	18	12	6
1025-11	18	15	12
1025-12	18	12	12
1025-13	18	18	12
1025-15	24	15	12
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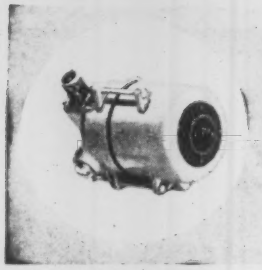

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Concluded from page 9

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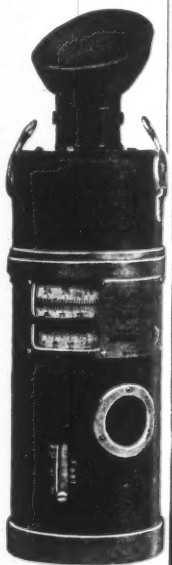

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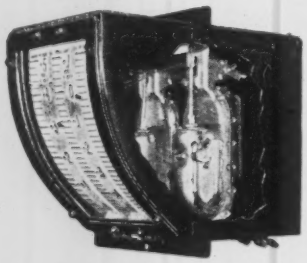

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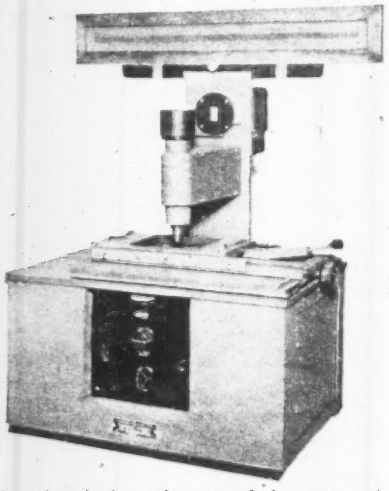
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department. Or write to Information Section, Instruments Publishing Company.

Transmittance Photometer

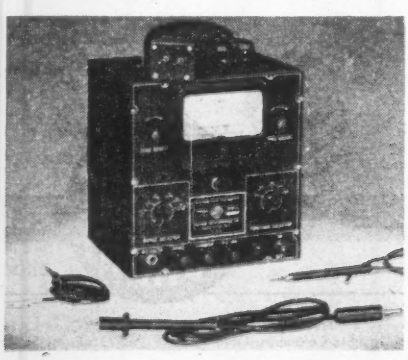
New Transmission Photometer, for accurately measuring light transmitted through small areas of spectrographic plates, is said to be desirable for use wherever spectrographic analysis is employed, also for microcolorimetric and



microchemical analyses and for measuring transmittance through solutions. Requiring a constant a-c. or d-c. power supply of 6 volts, with approx. capacity of 30 amps., photometer comprises a light source, an optical system, a long-scale mirror galvanometer, a photocell and a mechanical stage for accommodating the plate. Stage has a three-point ball-bearing suspension, is movable in three directions. Control knobs on front of instrument facilitate focal adjustment and control of optical-system diaphragms and filters. Instrument is said to be exceptionally easy to operate because all adjustments can be made and seen readily from a single position.—*Special Products Div., General Electric Co., Schenectady, N. Y.*

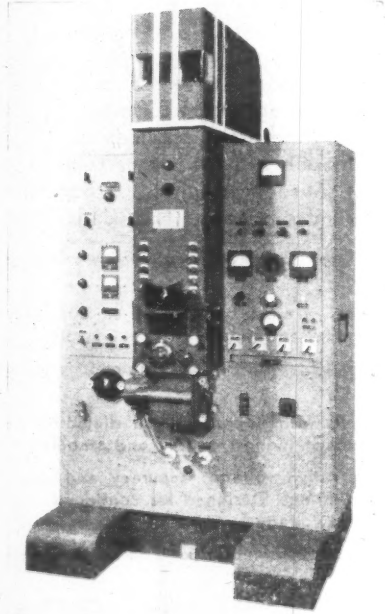
Vacuum-tube Voltmeter

New "Model 450 Vacuum Tube Volt-Ohm-Milliammeter" is said to incorporate many features which simplify operation and save time in production testing. A-c voltmeter measures from 50 cps. to 50 Mc; six d-c voltage ranges with input capacitance $<2\mu\mu f$. and input resistance of 11 megohms all ranges; d-c. current ranges from 50 ma. to 1 amp. in six ranges. The ohmmeter has 2% center-scale accuracy. Single zero adjustment for all a-c. and d-c. ranges. Occasional excessive overload will not damage instrument. Meter responds to average value of sine wave. Other features: one linear scale for all voltage and current scales; freedom from effects of temperature and humidity; measures ohms to 1,000 megohms without battery; battery used only for measurements below 10 ohms; voltage-regulated supply provides stable operation; adequate storage space in case for test probes and connectors.—*Reiner Electronics Co., 152 W. 25th St. New York 1, N. Y.*



Film-drum and Single-film High-speed Oscillograph

New self-contained industrial cold-cathode oscillograph records split-microsecond phenomena, is designed for use by engine manufacturers, power companies and re-

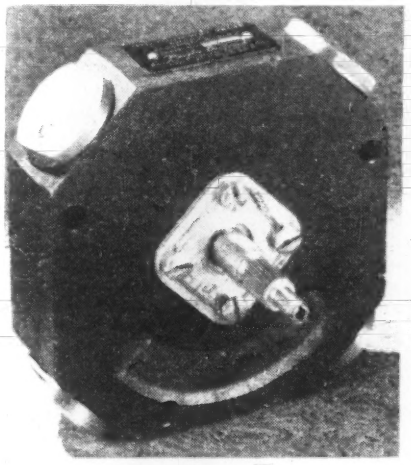


search laboratories. It can record single transients with respect to time, or two phenomena with respect to each other. Cathode is energized from a 50-kv. d-c. rectifier with a control to correct for line voltage variation. Electron beam is normally blocked by a target; impulse synchronized with phenomenon trips relay which bends beam around target so that it will strike fluorescent screen or film below. New streamlined unit consists of oscillograph proper in front of cabinet which houses all energizing and control circuits. Energizing

minals are enclosed except one bushing to urce of synchronizing impulse. Concen- ting coils, beam current indicator, and k valve, control intensity and size of ce on the film. Deflecting coils move o position of beam so as to record on tire area of exposed film. In addition to fluorescent screen for direct observation, trument contains a stationary film hold- taking a standard film for recording trical phenomena lasting a millisecond less, and may be operated with a rotat- g film drum for phenomena lasting from millisecond to 0.1 second. A photoelectric ntrol makes it possible to take an oscil- gram in one revolution of the drum, gardless of speed, preventing superim- sed waves.—*Westinghouse Elec. & Mfg. o., P. O. Box 868, Pittsburgh 30, Pa.*

Selector Valve

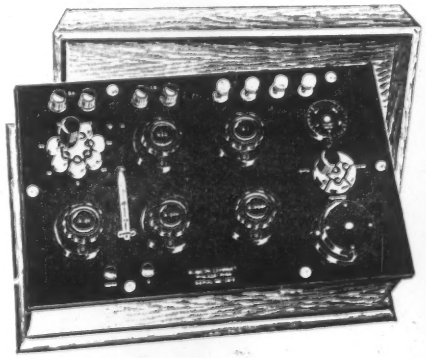
New "Altair AN6213-1" is an improved type of hydraulic four-way selector valve in which pressure drop is said to have been reduced by half over other valves of com-



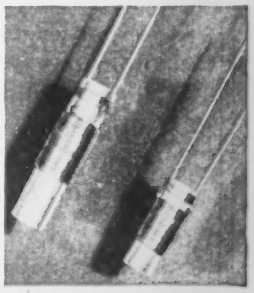
parable size. Valve is available for ⅜" tube size, is radial in design and utilizes patented plastic poppet valve elements. Body is a permanent-mold aluminum casting, cored fluid passages are oval instead of round in cross-section. This, coupled with extremely short distance traversed by fluid through valve, results in a pressure drop of only 11 lbs./in.² at 3 g.p.m. Simplicity of central cam design and radiating valve elements, and use of plastic poppets (no need of inserted seats), result in important weight savings; SAWE weight-approval seal, 0.86 lb. In addition to ⅜" tube size, ½" and ¾" valves also are available. Both carry AN approval.—*Pacific Div., Bendix Aviation Corp., 11610 Sherman Way, North Hollywood, Calif.*

Mueller Bridge

New "No. 1559" Mueller bridge is intended for precise measurement of resistance of three- or four-lead resistance thermometers (and other similar resistors within its



For many years, Shallcross has devoted 100% of its extensive resistor engineering and production facilities exclusively to accurate fixed wire-wound types. This has resulted in bringing to the field of electronics 11 basic time-tested types. These types can be readily adapted to meet all engineering needs as to terminal, mounting and other physical requirements. Special processing with materials found exclusively at Shallcross provides a complete selection of resistors which retain their accuracy and stability even under the most severe conditions of temperature, humidity and fungus.



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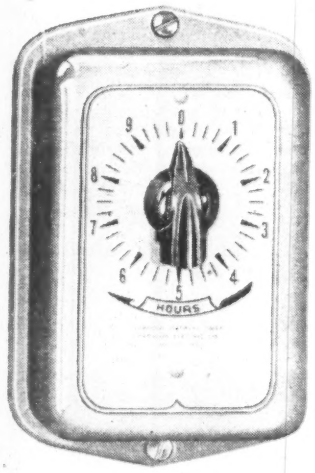
range). Its basic design follows that described by Mueller in *Bureau of Standards Scientific Paper No. 288*. Total measurement range is from 0 to 71.1110 ohms in increments of 0.0001 ohm. Ratio arms (two 1000-ohm resistors connected to ends of a single-turn slidewire) may be adjusted with great exactness to unity ratio value. Means are provided for convenient testing and adjustment of ratio value. Special precautions are taken to minimize effect of contact resistance in dial switches. Switches controlling the first two decades are so arranged that their contacts are in series with the high-resistance ratio arms rather than in the rheostat arm; switches controlling the other rheostat decades are used in the Waidner-Wolff arrangement. In measurement of three-lead resistance thermometers, resistance of one lead placed in "X" arm is compensated by resistance of a second lead inserted in the rheostat arm; battery connection is carried to the thermometer by third lead. Exact compensation requires identity in the resistance of the two compensating leads involved. Since this condition can seldom be realized in practice to the degree necessary for highly accurate work there is included on the bridge panel a mercury-contact commutator which permits attainment of extreme accuracy in measurement of four-lead thermometers irrespective of equality of lead resistances. Associated with the commutator is an improved plug-and-block assembly recently suggested by Mueller, whereby bridge may be conveniently arranged for determination of bridge zero or for verifying unity ratio value, all without disturbing external connections to the bridge. Resulting improved operation tinct advance over original design with detached commutator. Overall limit of error is 0.02% of the bridge setting or 0.00005 ohm, whichever is larger. — *Rubicon Co., Ridge Ave. at 35th St., Philadelphia, Pa.*

Interval Timer

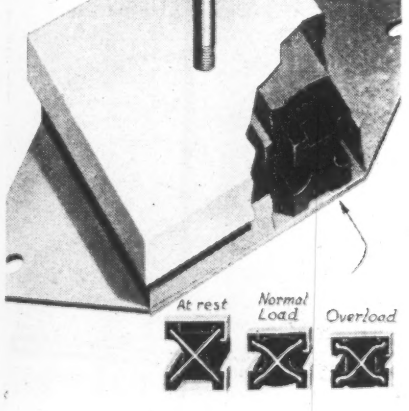
New "Model 2500" interval timer can be preset to allow a given operation to continue for "almost any pre-determined time limit" and to close or open a circuit at end of preset time. It is said to be particularly



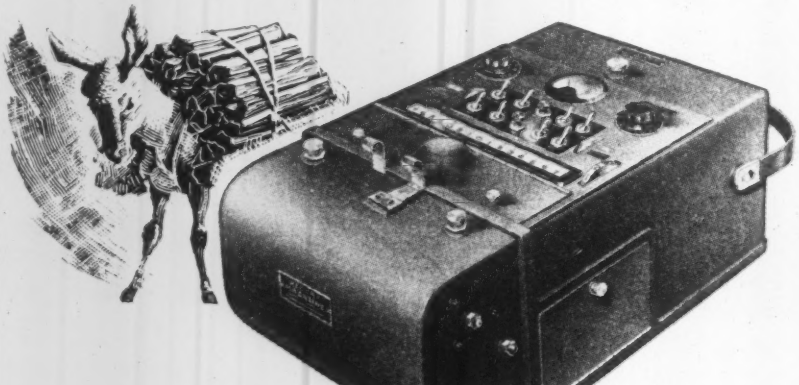
well adapted for use in plastic molding, rubber curing, batch mixing, heat treating, enamel baking, liquid agitation, light exposure, machinery operation, etc. Among features: (1) Switch — 1000-watt, s-p.d-t., fully enclosed, Underwriters approved. (2) Only two exposed gears—motor pinion and wheel, precision hobbed. (3) Motor — self-starting slow-speed synchronous industrial type, completely sealed. (4) No energy is required of clock motor to trip switch at end of preset time. (5) Ten time ranges: 0-15 seconds through 0-20 hours, available in all types of enclosures. (6) All parts rust-proofed and protected against corrosion. "2500 Series" can be mounted to surface of any panel, directly to surface of controlled equipment, also directly over and to any standard single gang switch box or handy box. Available for flush mounting or wall mounting with conduit connector. Overall dimensions 4⅞" high × 3⅛" wide × 2" deep.—*Paragon Electric Co., 37 West Van Buren St., Chicago, Ill.*

Anti-vibration Mounts

New type of vibration mount known as "Rexon," is said to be characterized by extreme simplicity in design and application and by virtual indestructibility in use. Determination of proper type of "Rexon" mount and its installation require neither engineering skill nor alteration of equipment. Only two standard types are required to isolate all kinds of vibration. Loading is not critical—a tolerance of ±10% being



SMALL *And* DEPENDABLE



That's the Hathaway Type S-12 Oscillograph. The last word in *performance* and *portability*, measures only 8"x9"x18", making it ideal for work in *aviation flight testing* and *geophysical work*.

Top panel control for convenience in operation, simple to adjust and operate, accurate and dependable response, ten to twelve channels, available with galvanometers covering a wide range of characteristics. Daylight loading of permanent 6" film or paper record, adjustable recording speeds, automatic record length control and successive numbering, simultaneous viewing with recording.

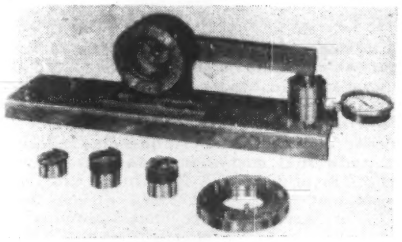
Order now for early delivery. Write for price and bulletin. The Hathaway Instrument Co., 1315 So. Clarkson Street, Denver 10, Colorado.

Hathaway INSTRUMENTS

missible. "Rexon" utilizes vibration mping properties of rubber in shear. ssibility of overloading the shear ele- nts is eliminated by "X" design of rub- element, which acts in shear at points "X" under normal loading but in com- ssion when load exceeds rated capacity mount. No rubber-to-metal bonds, either chanical or chemical, are used.—*Hamil- Kent Mfg. Co., Kent, Ohio.*

Aircraft Engine Starter Tester

New "Model A 760" is a portable test it that can be easily bolted to workbench testing clutch settings on starters used th engines up to 1000-in.^{3} displacement.



one-piece casting is mounted on a 7" steel hannel. To hold the starter to be tested, a " diam. mounting plate and one 3-tooth starter jaw with torque arm and piston and gage assembly are furnished as standard equipment. Ft.-lbs. of torque are registered on torque gage connected to piston assembly. Various accessories can be supplied as needed. Unit is 7" wide, 11" high and 28" long; weighs approx. 85 lbs.—*Airplane Mfg. & Supply Corp., Mfg. Div., 6853 Lankershim Blvd., North Hollywood, Calif.* [Corp. requests that inquiries be addressed to *H. N. Mabery, Jr.*, by name.]

Temperature Recorder-controller

New "Electronic Type Resistance Thermometer" suitable for indicating, recording and controlling temperatures between -100°F. and 1000°F. utilizes null balance principle and provides instantaneous balancing action: unbalance of measuring bridge is detected by electron tubes without galvanometer or other moving parts. Reliable performance and accurate calibration over long periods of continuous operation are said to result from sturdy design. Instrument illustrated in Fig. 1 indicates, records and controls temperature. A 29" indicating scale which circles the chart may be read from 50 feet. Pointer reading coincides with that of recording pen. Indicating, recording and controlling mechanisms are all driven by the same reversible electric motor which adjusts the slide-wire resistance to balance the measuring bridge. This motor is continuously connected to the electronic control unit which

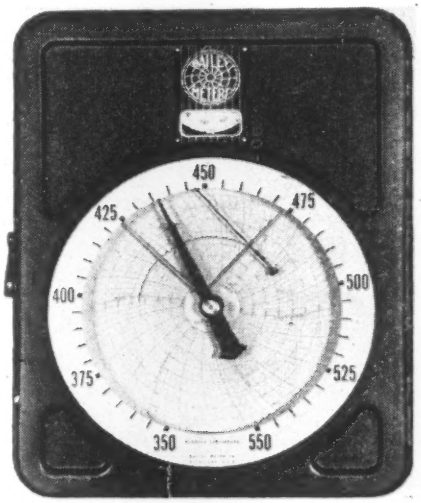


Fig. 1

POWER RESISTOR DECADE BOX

Covers resistance range of 1 ohm to 999,999 ohms.

★

Each decade dissipates up to 225 watts. Greenohms (wire-wound cement-coated power resistors) used throughout. Glass insulated wiring.

★

Six decade switches on sloping panel.

★

Maximum current per decade: 5, 1.5, .5, .15, .05 and .005 amp.

★

Attractive frosted-gray metal case. Etched black-and-aluminum panel. Dual binding posts for left- and right-hand duty.

★

Grille at bottom and louvres at side for adequate ventilation. Baffle plate protects switch mechanism against internal heat.

★

13" long, 8½" deep, 5¾" high. Weight, 11 lbs.

★ Since its introduction several years ago, the Clarostat Power Resistor Decade Box has become a "must" among busy engineers, laboratory workers, maintenance men and others. Especially so during the hustle and bustle of war work.

Definitely in a class by itself. There's nothing else just like it. Note that it is a *power resistor* decade box. That means the introduction of the correct resistance value for any circuit or application for use under actual working conditions, at the mere twist of the knobs. The resistance which provides the correct operating conditions is then read directly off the dials. No calculations required. No guesswork. No time-consuming routine. No wonder the Clarostat Power Resistor Decade Box pays for itself in short order.

★ **Write for literature . . .**

Descriptive bulletin sent on request. Likewise literature on controls or resistors in which you are particularly interested. Let us quote on your requirements.

CLAROSTAT *Controls and Resistors*

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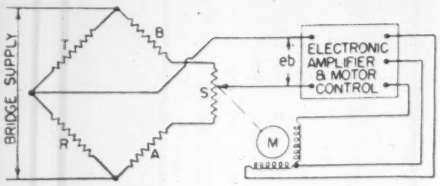
in turn is continuously connected to the measuring bridge as shown in Fig. 2. Resistance thermometers may be provided with as many as four recording pens, each provided with its own continuously-connected electronic control unit and measuring bridge, thereby providing instantaneous response to changes in temperature. Primary element is a platinum resistance wire wound of a mica form and held between two mica sheets clamped by a metal frame, all in a protecting well permanently installed in pipe line, furnace wall, duct, etc. This element is represented in Fig. 2 by resistor *T*. Resistors *R*, *A* and *B* are fixed and are designed to provide proper range of measurement. Adjustment of slidewire contact on resistor *S* subtracts resistance from *A* and adds resistance to *B* or vice versa. Thus, bridge is balanced by adjusting ratio of bridge arms, obviating necessity of carrying bridge current through the slidewire contact and preventing variations in contact resistance from affecting calibration. Since a.c. is used for



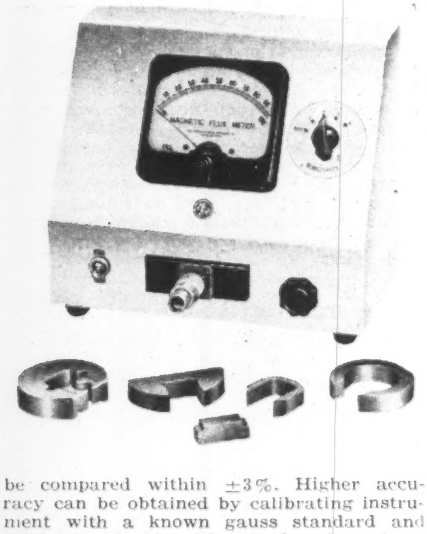
T•TEMPERATURE SENSITIVE PLATINUM RESISTANCE
A,B & R•FIXED RESISTORS M•SLIDEWIRE DRIVE MOTOR
S•SLIDEWIRE

Fig. 2

bridge, no battery source of bridge voltage is needed. Standard voltage cells and voltage standardization equipment are not required. "Bailey Air-operated Control," "Bailey Electronic Control" or contacts for on-off electric control may be provided for as many as two temperatures by the multiple-pen recorder-controller. Requisite control mechanisms are mounted inside case and are actuated by the same reversible motors which drive the recording pen. Alarm contacts may be provided for any or all of the recorder units. These contacts are operated by an adjustable cam which may be set to trip at any desired position of the recording pen. Temperature-measuring circuits may be arranged to calculate the sum, difference and ratio of temperatures. Calculated results are recorded directly "in the form of news instead of history" and it is said that much time and labor may be saved by the electronic calculating method as compared with manual calculation from chart records and log sheets.—*Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.*

Magnetic Fluxmeter

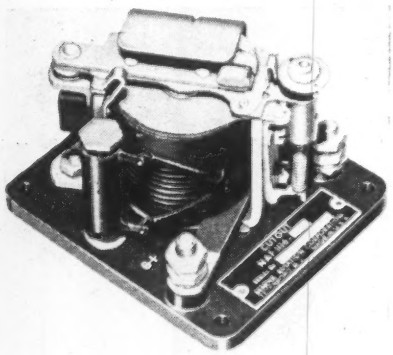
New "Model 256" fluxmeter utilizes an electronic circuit so connected to indicator that when exploring inductor is placed in a magnetic field, indication will be in proportion to that field. It is designed to operate from 105-120-volt 50-cycle a.c. (other voltages and frequencies available at additional cost). Built-in voltage regulation is provided so that indication is independent of normal line voltage fluctuations. Magnetic flux measurements can

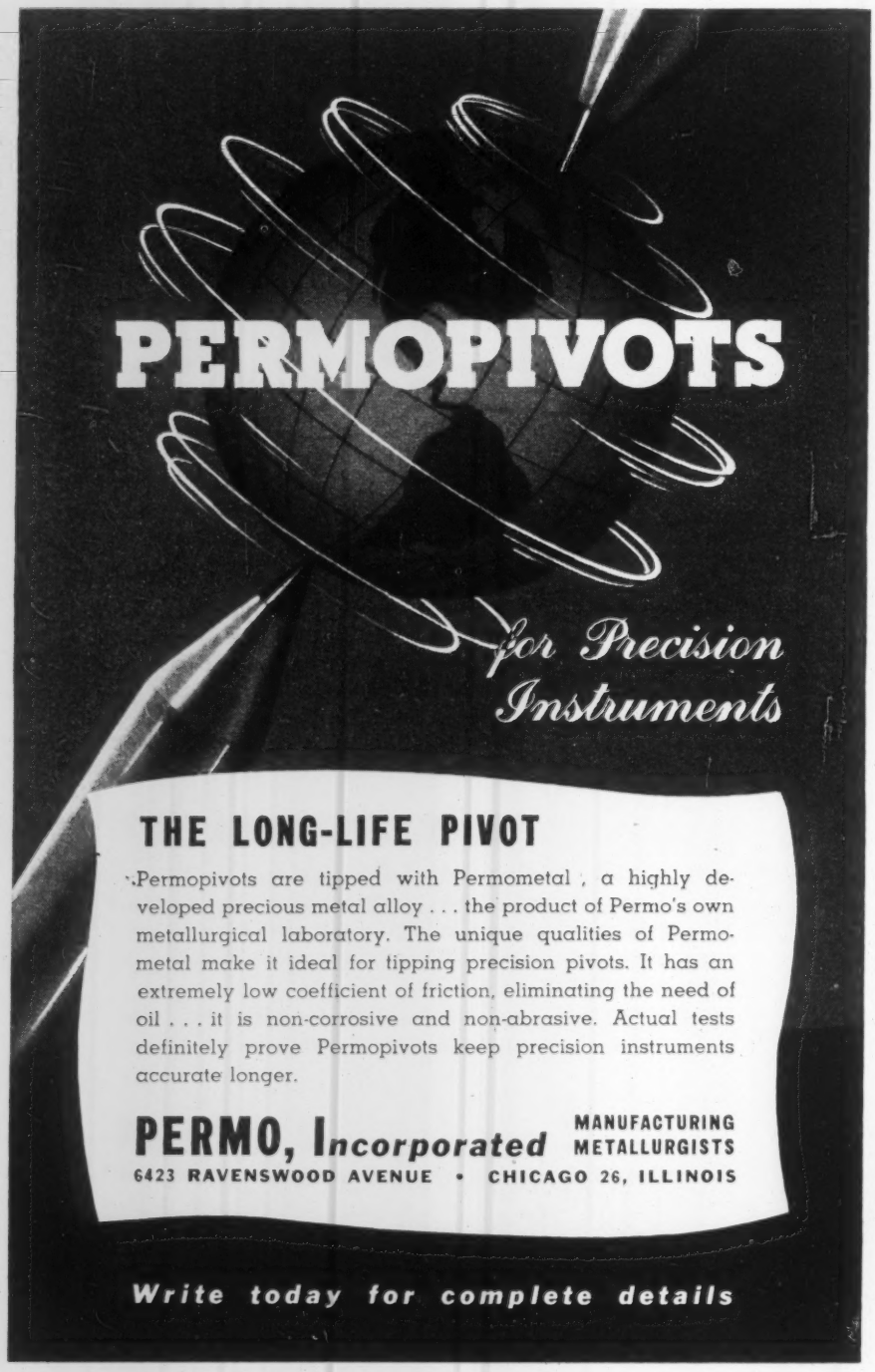


be compared within ±3%. Higher accuracy can be obtained by calibrating instrument with a known gauss standard and using it shortly afterwards. One four-position control serves dual purpose of turning instrument off and selecting three sensitivity positions. Balance control is used to pre-set indicator at zero. Exploring inductor can be made with a minimum dimension of approx. 3/16", to measure flux density in small air gaps. Dimensions, 9½" wide, 10½" high, 5" deep; net weight 10 lbs.—*Hickok Electrical Instrument Co., 10519 Dupont Ave., Cleveland 8, Ohio.*

Reverse Current Cutouts

New "Eclipse Reverse Current Cutouts" are designed to prevent reverse flow of current to generators in aircraft power systems utilizing batteries and generators

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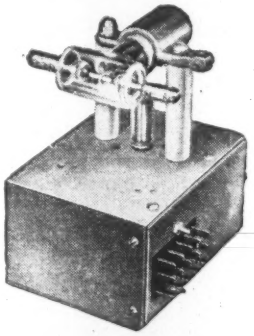
as power source. They automatically disconnect generators from electrical systems when generator voltage drops below system voltage; also operate as generator automatic main switches. They are said to operate satisfactorily in any mounting position when adjusted in that position. Changes in cutout temperature have minimum effect on operation. On two of the four announced types, armature leads are shielded to prevent change in cutout setting through handling. Silver alloy contacts are said to have long life and low voltage drop. Adjustment knob is conveniently accessible and automatically locked.—*Eclipse Pioneer Div. Bendix Aviation Corp., Teterboro, N. J.*

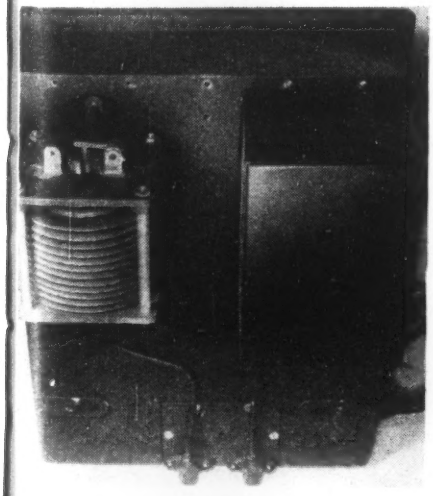
Vacuum Switch Keying Relay

New "Type 78CCA100" Vacuum Switch Keying Relay was originally designed for aircraft use, has many applications in other fields. Relay is said to be designed for extreme reliability in holding its adjustments, is of new, simplified and rigid construction, with minimum of parts, all of them readily accessible for inspection or adjustment. Tests show a life far in excess of five-million-operation minimum required for units of this type. Relay has seven poles, including one double-throw pole which handles high-voltage r-f. currents by means of a vacuum switch. All high-voltage parts are rounded to reduce corona.—*Struthers-Dunn, Inc., 1321 Arch Street, Philadelphia, 7, Pa.*



Bellows-type Industrial Pressure and Vacuum Instruments

New bellows-type units have been added to maker's line of industrial and vacuum recorders and controllers. Cases, charts and other Brown features are unaltered except in minor respects; appearance of new units is shown in rear-of-case photograph (one unit with cover removed). Two general types of units are available: (1) single-spring type for pressure above atmospheric, (2) double-spring type for



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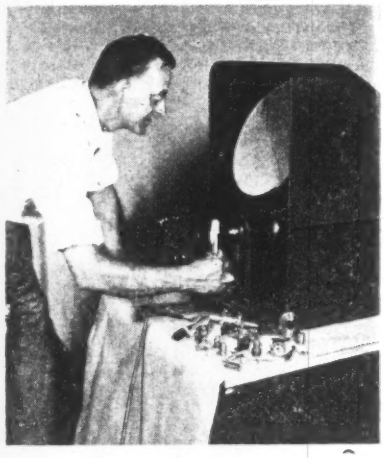
vacuum and compound ranges. New units are available in various total ranges, from a minimum range of 0-5" water to a maximum of 0-50" water. Design and construction are said to make available in plant applications, a combination of sensitivity and accuracy usually found only in precision laboratory instruments: negligible tapping error, hysteresis less than 0.2% full-scale between up-scale and down-scale readings "even under the most stringent operating conditions"; sensitivity within $\frac{1}{8}$" water; calibrated accuracy of $\pm 1\%$ of full-scale span. Ample force is available for control regardless of low pressure, by reason of large bellows area. Bellows and springs have been properly related in size through careful testing. Connection tubing of 3/16" ID has sufficient area to prevent liquid collecting. Provision is made for draining condensable vapors from bellows shell by means of large-diameter connecting tubing. Instrument also provides for easy adjustment; zero and calibration adjusting screws are equipped with accessible knurled knobs and their mechanisms are of micrometer type. In addition, shaft bearing supports are castings which eliminate misalignment and resulting friction. Another advantage of new type is that the same bellows is used when pressure ranges are changed, requiring only installation of proper spring and recalibration. Spring, being external to bellows and out of contact with fluid being measured, is not subject to corrosion. On vacuum and compound ranges the spring is corrosion-resistant. Within bellows, and in contact with fluid being measured, it is made of stainless steel. Range may be changed in the field. —*Brown Instrument Co., 4482 Wayne Ave., Philadelphia 44, Penna.*

Optical Projector

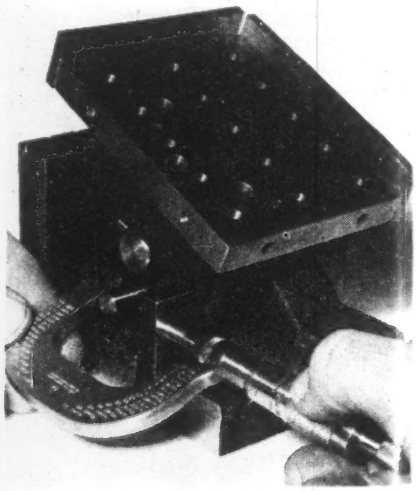
New "Model P2.5" bench type optical projector is designed for easy setting up and operation with a minimum of mechanical adjustments. According to manufacturer, unit is ruggedly constructed and consists of the finest optical lens components combined with scientifically cor-



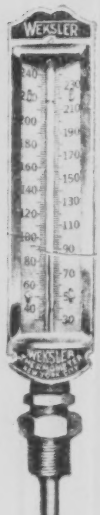
light source, providing excellent screen image definition at all magnifications. By reason of projector's simple design, unskilled operators are said to be able to use this equipment in connection with all types of work suitable for optical projection checking. Production speed of inspection can be effected through the use of ordinary staging V-blocks or other simple holding fixtures. Projector has a large working capacity and is furnished with a standard full-size 14½" diameter working screen. Stage area measures 4" × 4". Overall length of unit is 42"; width, 18"; height, 32" shipping weight, approx. 200 lbs. "Portman Bench Model P2.5 Optical Projector" can be furnished with a choice of 10×, 25×, 50× or 90× magnification lens unit and may be operated on the ordinary factory lighting circuits of 110 volts.—*Portman Optical Co., 70 Mill Rd., New Rochelle, N. Y.*

Angle Setting and Measuring Device

New "Bemisine" (named after its inventor I. W. Bemis) is a hinged-table device for setting or measuring any angle from 0° to 90° to one minute of arc in one minute of time; requires only a 2" capacity micrometer and reference to standard table of sines and cosines; has provision for holding small work-pieces for grinding, machining or inspection. It is recommended especially for use with grinding and jig boring equip-



INSTRUMENTS FOR INDUSTRY



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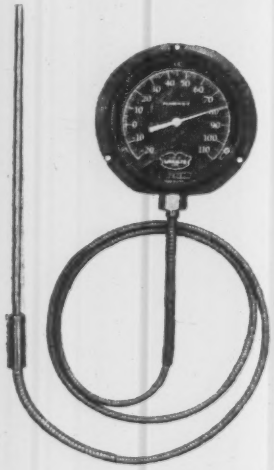
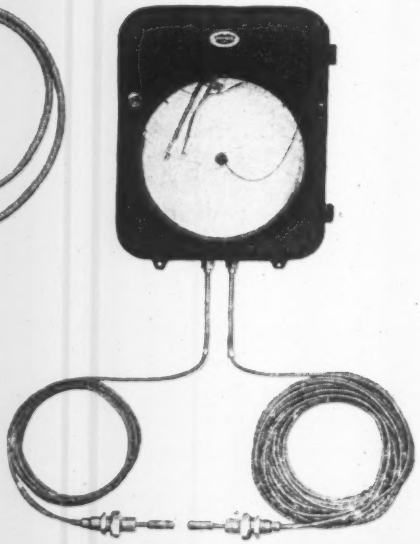


Industrial Type Thermometers have a "V" shape bronze case, removable glass front, red reading or yellow back tube, and may be had with any desired stem.

Dial Indicating Thermometers in a phenol condensate case, with a 4½", 6" or 8½" dial, are mercury, vapor or gas actuated.



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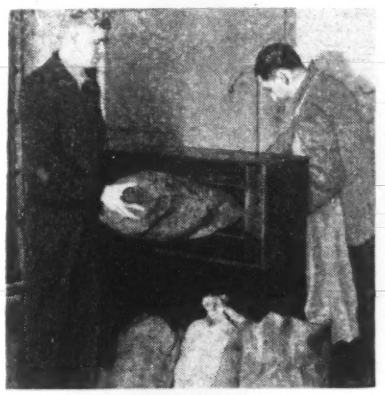
Metal Detector

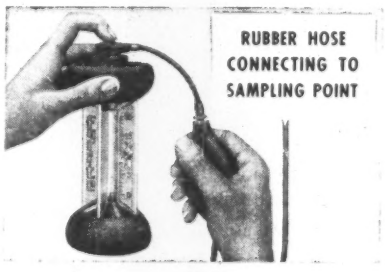
New "Alnor Forewarn Metal Detector" signals presence of tramp iron or steel in materials where such ferrous materials would be dangerous or undesirable. Unit is



modification of "Alnor Detector Equipment", used in penal institutions to search inmates and visitors to prevent smuggling guns, files, sawblades, etc. New detector is said to be adapted to practically any handling requirements, in stationary units, or for use with conveyors. It consists of search coil, amplifier and supervisory signals. Amplifier and signals may be a part of search-coil system, or remotely located. Sensitivity is adjustable. Practically any size opening can be provided to suit requirements of hand or gravity feed or for use with continuous conveyor, or periodic flow with manual control. Size of ferrous parts which system is able to detect depends upon flow through search coils and size of search area.—*Illinois Testing Laboratories, Inc., 420 North La Salle St., Chicago 10, Illinois.*

Oxygen Indicator

New "Fyrite Oxygen Indicator" enables rapid determination of O_2 with an accuracy of 0.5% O_2 at any point of scale. Instrument employs principle of chemical absorption: a sample of gas or atmosphere to be tested is pumped into it with aspirator bulb, as illustrated. Release of finger pressure on



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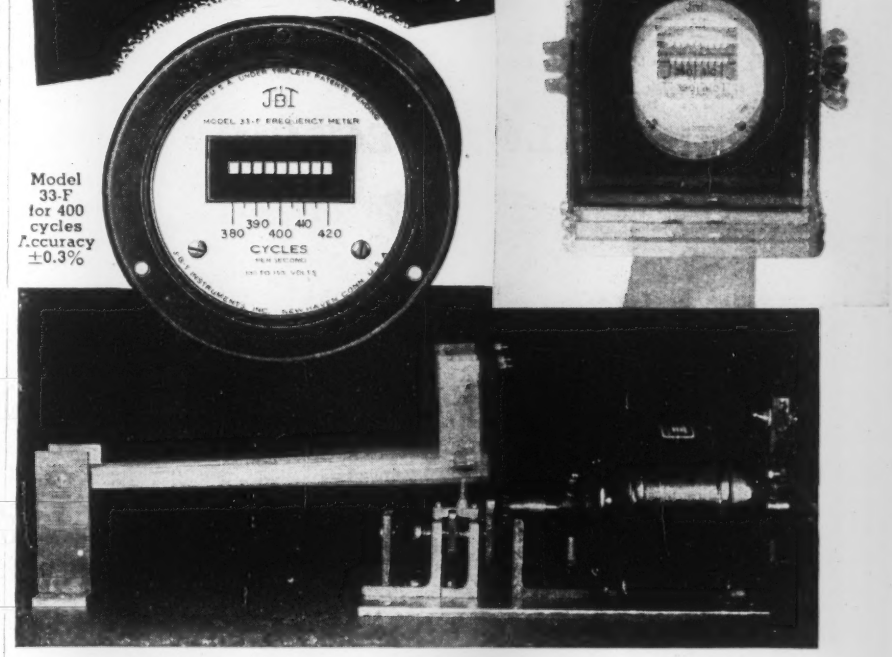

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During the run, meters are rotated in the clamp to subject the reeds to stress and shock not only in their normal plane of operation but also in cross planes. They also undergo 24 hour vibration tests and single impact shocks of 50 G's and above—through all planes.

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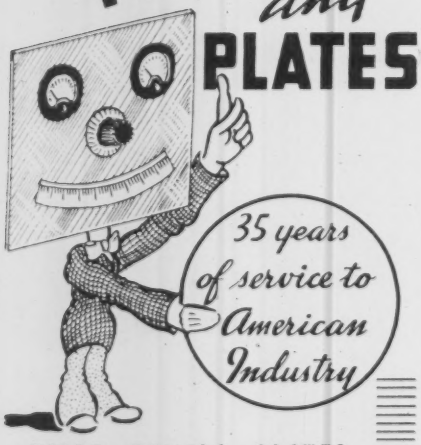

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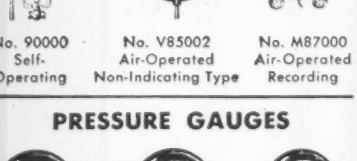

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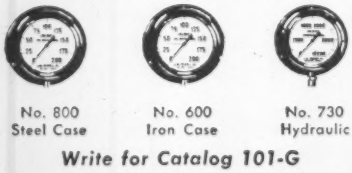

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Manufacturers of Temperature Instruments

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connector at end of rubber tubing automatically locks sample in calibrated measuring chamber. "Fryite" is then turned bottom-side up, and back again, which causes absorbing fluid to mix with sample. Absorption of oxygen creates a suction which draws absorbing fluid up into graduated tube in an amount equal to O_2 absorbed. Level of the fluid column shows O_2 percentage, which is read directly on graduated scale. The standard range is 0 to 2[illegible]. Entire test, including pumping of sample, takes about 40 seconds. Process is automatic, does not require previous instruction, skill or training. There are no valves, clamps or leveling bottle to manipulate. Instrument's accuracy is said to be unaltered by vibrations or shock. — *Bacharach Industrial Instrument Co., 7000 Bennett St., Pittsburgh 8, Pa.*

Equipment for Recording Vibrations, Strains, etc.

New "GLM Dynamics Measurement Equipment," designed primarily for flight testing, comprises various types of small remote-indicating pick-up units. Responses of a number of pick-ups are recorded

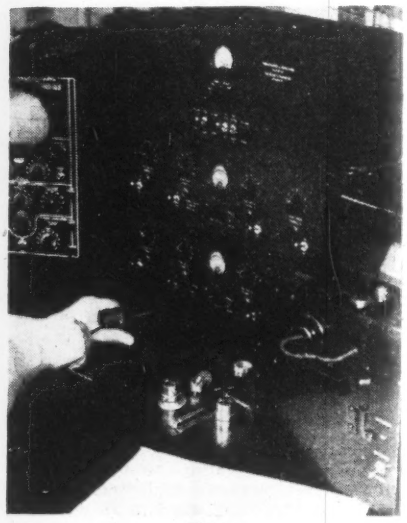


Fig. 1

simultaneously on sensitized paper. System makes use of modulated carrier wave principle: pick-up contains one or more variable-impedance elements and variations in magnitude being measured cause proportional variations in pick-up impedance, thereby changing balance condition of modulating bridge circuit. Since bridge is fed by a carrier signal of constant frequency and voltage, bridge output signal is proportional to the change being measured. Modulated carrier is amplified and transformed by means of a full-wave rectifier into a pulsating unidirectional current of twice carrier frequency. This current is fed to a galvanometer coil in a recording oscillograph which makes a permanent photographic record of that envelope by means of a light beam deflected by the galvanometer mirror. Carrier wave is introduced only to facilitate amplification of pick-up signal which may be of low or zero frequency; is eliminated after amplification is obtained. *Components:* Fig. 2 is a block diagram. D-c. power supply distributes low-voltage filament current and regulated high-voltage plate current to components of equipment, operates from 12-volt storage batteries or in conjunction with a-c. power supply. Master oscillator generates a carrier signal at 1,500 c.p.s. which is fed through a buffer stage in each amplifier channel to the modulating bridge connected to that channel. Amplifier channels are constructed in banks of four, each channel consisting of two high-gain stages and a third power-amplifier stage. Amplifier output is fed through a selenium rec-

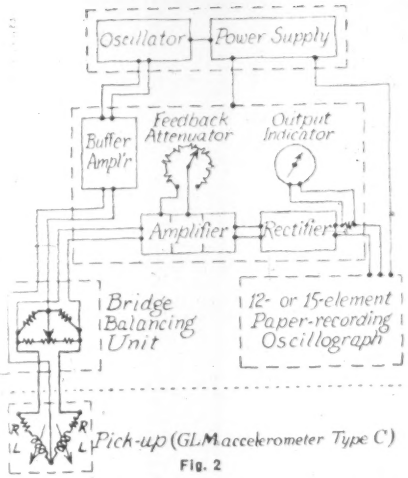
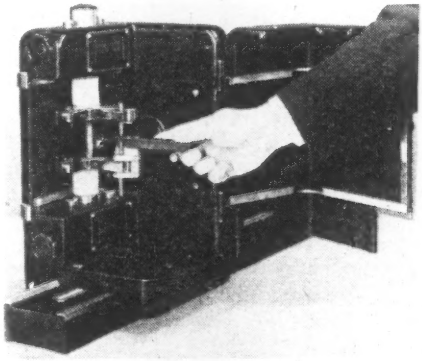


Fig. 2

ier to transform the carrier to unidirectional current, and thence to the oscillograph galvanometer, whose dynamic characteristic serves to filter carrier ripple passing rectifier. Galvanometer element has negligibly small response to carrier frequency but has uniform and maximum response throughout the range of frequencies which are measured. The GLM accelerometer pick-up is of variable-reluctance type and is built to give substantially linear response to accelerations from zero to ±20 *G* at frequencies from zero to 60 c.p.s., can be adjusted for wider ranges or (for increased sensitivity) for considerably narrower ranges. "Type B" employs one active coil, "Type C" employs two active coils whose inductances change in opposite directions. Recording oscillograph ordinarily used contains twelve or fifteen galvanometer elements, with provision for simultaneous viewing and recording of galvanometer motions and a 0.01-sec.-interval timing element. Records are made on positive recording paper, 6" or 8" wide depending upon the type of oscillograph. Equipment includes complete set of leads with AN aircraft type plugs. Also available is "GLM Type 2-A" sinusoidal-vibration calibrating table with 1" max. amplitude and variable frequency.—*The Glenn L. Martin Co., Baltimore 3, Md.*

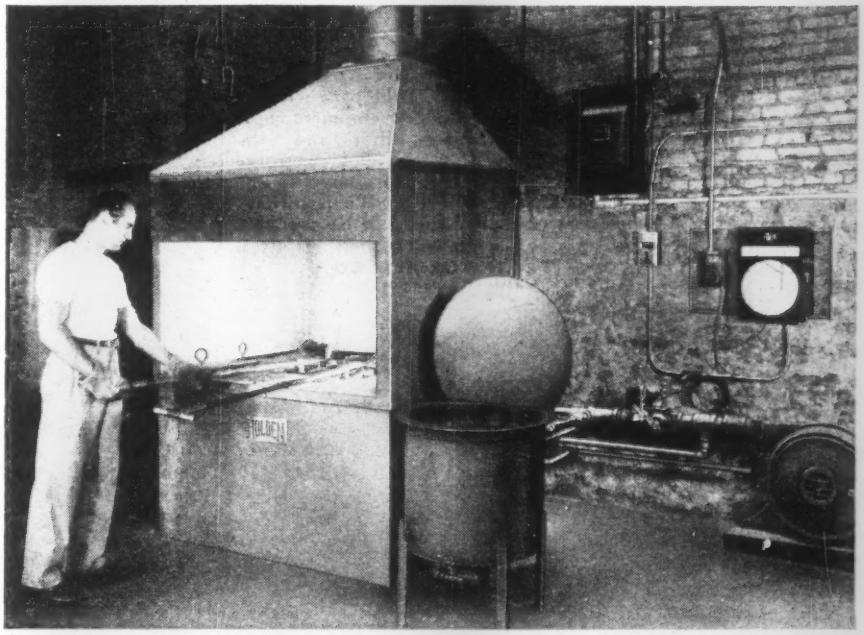
Universal Arc-spark Stand

New "ARL-Dietert Universal Arc-Spark Stand" is said to combine all desirable features of conventional stand used in general arc work, of jig-loaded stand used for metal-rod analysis, and of Petrey Stand used for metal-plate analysis. Unit is completely enclosed. Door is provided with safety switch to prevent shock hazard and with an eye-saving dark-red window which allows good discharge visibility. Stand is ruggedly constructed from large aluminum castings. Massive steel electrode holders are water-cooled. Insulated tubing on water system prevents power leakage or breakdown even when used with the high-voltage spark unit. Friction drive for positioning electrodes provides 1" continuous travel on both upper

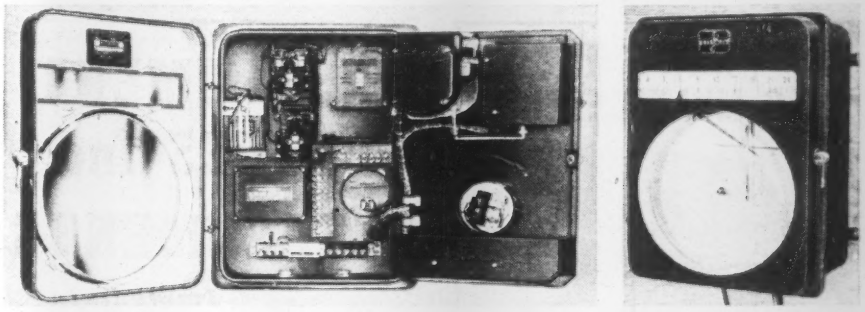


PORTABLE POWER PROBLEMS

THIS MONTH—BRISTOL PYROMASTER



INDUSTRIAL PROCESSES are accurately recorded, indicated and controlled by the Bristol Pyromaster Self-Balancing Potentiometer. In the illustration above, a Pyromaster maintains temperature control of a gas-fired furnace, used for case hardening steel parts.



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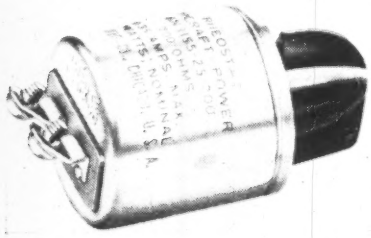
NEW YORK TRANSFORMER CO
76 WAVERLY PLACE, NEW YORK 3, N. Y.

and lower holders, minimum spacing of 5/8" between holders and maximum of 2 5/8". Calibrated stops limit each electrode holder's motion at top and bottom, are adjustable to 0.002" with vernier knob to allow exact duplication of a wide variety of settings. For jig-loading, holders are locked in place and an accompanying jig is used for spacing sample rods rapidly and accurately. Another jig (also furnished) may be used for spacing rod-carbon electrodes for arc work. Instrument is easily convertible for use with flat specimens by raising (or removing) upper electrode and putting into place a rotary table, pinned for exact positioning, which allows sparking at three positions on flat specimen by moving an external lever. A 3° tilt of table prevents shadowing of discharge by overhang of sample. Height of sample is maintained for all three positions and table height is adjustable to 0.001", allowing duplication of various electrode positions. A fourth position on external lever provides a gage over lower electrode, allowing for spacings of 1, 2 or 3mm. between sample plate and counter electrode. Positive sample holder exerts spring tension against top of the specimen, "insuring perfect electrical contact at all times, irrespective of the condition of the sparking surface." Unit includes high-tension cables 8 ft. long. Overall dimensions 9" wide, 14" high, 8" deep. Weight approx. 30 lbs.—*Harry W. Dietert Co., 9330 Roselawn Ave., Detroit 4, Mich.*

Aircraft Rheostats

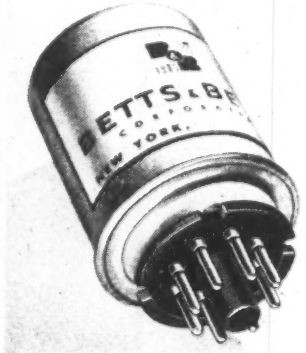
Two new approved power rheostats for aircraft, made in accordance with AN-R-14a (drawing 3155) have many of maker's rheostat features plus new improved control



protection. They are lighter than the allowable weight specified. They meet the salt spray corrosion test and other critical tests and operate satisfactorily in temperature range from —55°C. (—67°F.) to 70°C. (158°F.). Two sizes: "Model J" 50-watt, "Model H" 25-watt (illustrated). Linear or taper wire-wound, in various resistance values, with "off" position as required. Totally enclosed in corrosion-resisting metal container. Complete with knob as shown.—*Ohmite Mfg. Co., 4835 Flournoy St., Chicago 44, Ill.*

Midget Type Relays

New "Corosealed" relay is a midget type relay especially designed for communication, electronics and aviation applications. Units are hermetically sealed in a metal shell said to assure perfect performance



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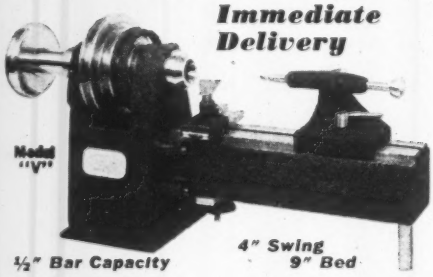

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Ferrous-materials Comparator

New "Cyclograph" permits simple comparisons of ferrous materials as to analysis and heat-treatment, utilizes transformer principle of operation: A 23-cycle exciting

current is fed into primary coil while output of secondary is controlled by magnetic characteristics of a metal sample introduced into coil. Voltage from secondary is filtered and fundamental 23-cycle wave is impressed on horizontal axis of cathode-ray tube. Third harmonic is viewed on vertical axis. First and third harmonics will vary in phase and amplitude with variations in analysis and heat-treatment of steel or iron. Sorting of commonly-used SAE steels is practical although, in some cases, observable difference may not be sufficient for sorting production lots of parts. About 80% of occurable mixtures of two types of iron or steel can successfully be sorted by "Ferrograph." Low-frequency exciting current has an advantage over 60-cycle in that magnetizing flux reversals are slow enough to give some appreciable effect from residual magnetism. A long-persistence screen is used in c-r. tube to avoid flicker from low frequency. A relay turns cathode-ray beam off automatically unless there is a sample in test coil. Flux in test coil can be varied widely. It is possible to correlate with different variables by using different flux densities in "Ferrograph" coil. Calibrated scale provides ten divisions per inch, with 10th divisions accentuated. Instrument is fully portable, is designed to withstand rough usage in laboratory, shop, or field, operates on 115 volts, 40-60 cycles. Dimensions: 12½" wide, 17¼" high, 23¾" deep. Weight, 100 lbs.—*Allen B. Du Mont Laboratories, Inc., 2 Main Ave., Passaic, N. J.*

Absolute-altimeter Indicator

New absolute-altimeter, based on radio principles, indicates distance to nearest solid object: ground beneath or a cloud-hidden mountain, is a development of engineers of several organizations including RCA and the Navy. Illustration shows only the special indicating instrument, developed

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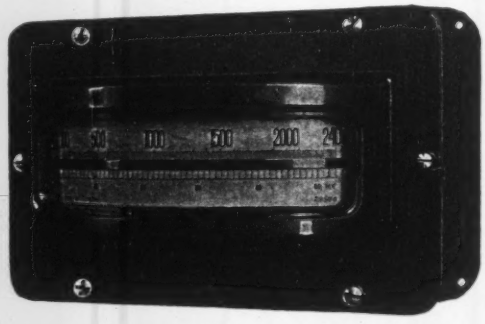

WALL TYPE W-1

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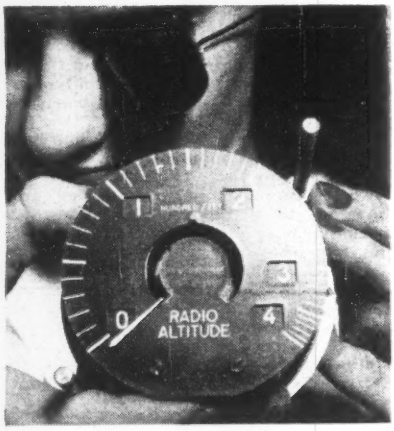
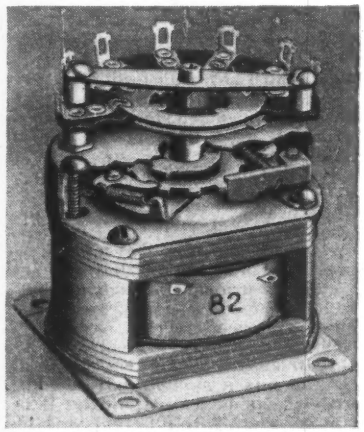


by Westinghouse, which is part of system a d-c. milliammeter of circular-scale form fully compensated for ambient temperatures from —67°F. to 18°F. Over normal range of temperature, accuracy is within 1%. Instrument has two scales, 0-400 ft. and 0-4000 ft., selected by turning an external switch. Only one scale shows at a time behind windows in dial face, thus preventing reading wrong scale. Instrument, necessarily made as light as possible because of its use in planes, also combines master control switch for entire absolute-altimeter system. For distances within the all-important region of 10 to 400 feet, indication is accurate to within five feet. "Many a pilot has been able to land his plane on a runway he could not see," it is said.— *Westinghouse Elec. & Mfg. Co. East Pittsburgh, Penna.*

Stepping Relay Mechanism

New "Type 82 Rotary Relay Stepping Unit" is a compact twelve-position driving mechanism which operates a shaft extension through 360° in twelve progressive steps. When built up as shown above, unit provides a twelve-position selector switch, which indexes one position for each momentary current impulse. Unit will drive up to



three wafer switches, or any other load not in excess of 12 oz.-in. torque, can be made to operate clockwise or counter-clockwise. Actuator can be furnished (1) as a direct drive indexing load with current impulse, thus switching operation is complete the moment the solenoid operates; or (2) as a spring drive, indexing load following the current impulse, in which case the switching operation is accomplished by spring action following each current impulse. Current required to operate this unit will depend upon torque required for a particular application. Manufacturer will furnish a suitable coil if load is specified. For a 12 oz.-in. load a 12-ohm coil drawing 2 amps from a 24-volt d-c. supply would be required. Unit operates on d.c. only.—*Price Brother Co., Frederick, Md.*

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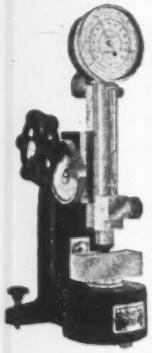

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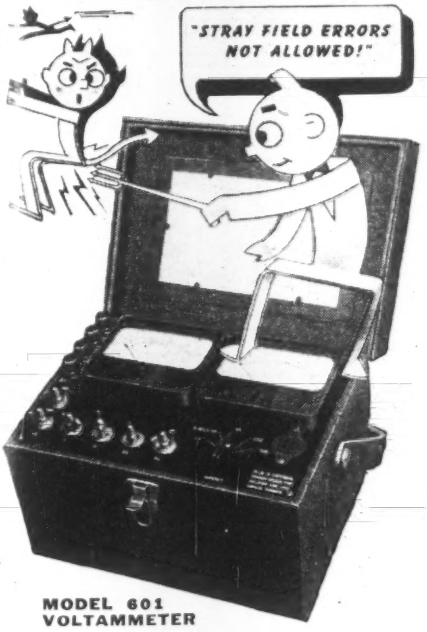

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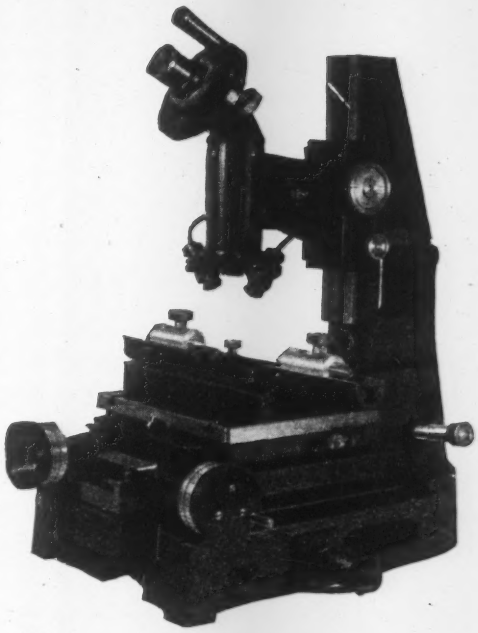

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INSTRUMENT SOCIETIES CALENDAR

City	Society	Secretary	Date	Place	Subject	Speaker
Atlanta, Georgia	Georgia Society for Measurement & Control	Robert E. Geminert, P.O. Box 1714, Atlanta				
Baltimore, Maryland	Baltimore Industrial Instrumentation Society	J. J. Seglets, 35 S. Potomac St., Baltimore 24	Jan. 30(C)	Engineers Club, 6 W. Fayette St., Balto.	Electrical Measurements of Non-elec. Quantities	Perry A. Borden, The Bristol Co.
Chicago, Illinois	Chicago Society for Measurement & Control	A. J. Butler, c/o IHC, 2626 W. 31st Blvd., Chicago	Feb. 5(B)	M&M Club, 237 Merchandise Mart	Theory of Boiler-feed-water Regulation	E. W. Nick, Pres. Northern Equip't Co.
Cleveland, Ohio	Cleveland Instrumentation Society	W. A. Stubblefield, 2085 W. 104th St., Cleveland 2				
Fort Worth, Texas	Fort Worth Electronics Club	Ralph Ely, 1116 E. Arlington, Fort Worth	Jan. 18(A)	Texas Hotel, Fort Worth	Feed-back Dimmer Controls	M. M. Barnard, Ft. Worth Transit Co.
Gulf Coast (Texas)	Gulf Coast Instrument Maintenance Men's Ass'n	T. H. Pierson, 3030 Roberts St., Beaumont, Texas				
Hartford, Conn.	Hartford Society for Measurement & Control	S. J. Zelle, Bridgeport Thermostat Co., 1225 Connecticut Ave., Bridgeport, Conn.	Jan. 16(B) Mar. 20(B) May 15(B)	Bond Hotel Bond Hotel Bond Hotel	Industrial Applications of X-rays Electronics, Fad or Servant Automatic Temperature Control	J. H. Bly, Materials Lab. Pratt & Whitney Aircraft Dr. Paul G. Weiller C. O. Fairchild, C. J. Taglabue Mfg. Co.
Kansas City, Missouri	KC Industrial Instrumentation Society	Gordon H. Burke, 1527 Broadway, Kansas City, Mo.	Jan. 30(B)	Bluebird Cafeteria	Gas Pressure Regulators	C. C. Abbott, Pittsburgh Equitable Meter Co.
Newark, N. J.	Society for Measurement & Control (New Jersey)	Robt. H. Gray, 1 Whippoorwill Way, Mountainside, N.J.	Feb. 6(B)	Essex House	"Information Please" program	H. F. Moore, Std. Oil Dev. Co., Chairman
New York, N. Y.	New York Society for Measurement & Control	H. R. Kalbfleisch, 144-35 No. Blvd., Flushing, N. Y.	Jan. 30(B)	Columbia U. Men's Faculty Club, 400 W. 117th St.	The Fordham Lie Detector and Its Applications	Dr. Joseph Kubis, Fordham University
N. Indiana	Northern Indiana Soc. Measurement & Control	K. M. Frame, 25 Ruth St. Hammond, Indiana				
Philadelphia, Pa.	Philadelphia Society for Instrumentation	G. E. Gress, c/o ATC, 34 E. Logan St., Philadelphia	Jan. 17(B) Feb. 21(B)	Engineers Club, 1317 Spruce St. Engineers Club	Sylphon Bellows—Manufacture and Applications Liquid Level Control	J. V. Geisler, Pres., Fulton Sylphon Co. P. Elfers, Fisher Gov'r
Pittsburgh, Pa.	American Society for Measurement & Control	L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pittsburgh 13	Jan. 22(B) Feb. 26(B) Mar. 26(B) Apr. 23(B) May 28(B)	Roosevelt Hotel Roosevelt Hotel Roosevelt Hotel Roosevelt Hotel Roosevelt Hotel	Liquid-in-glass Thermometry Inter-connected Controls Combustion Control Surface Finish Instruments Process Control	W. D. Lavercll, Precision Thermometer & Inst. Co. J. Pelletere, Gulf Oil Co. W. Pray, Askania Reg. W. Mikelson, G.E. W. B. Heinz, Cochrane Corp.
St. Louis, Mo.	St. Louis Society for Instrumentation	Gus Holubeck, Union Electric Co., Venice, Ill.				
Toronto, Ontario	Canadian Society for Measurement & Control	T. C. Agnew, Minneapolis-Honeywell Reg. Co.	Jan. 18(B)	Diana Sweets, 188 Bloor St. W., Toronto	Electronic Self-balancing Potentiometers	Fred E. Hessey
Washington, D. C.	Instrument Society of Washington	W. A. Wildhack, 328 N. Oxford St., Arlington, Va.	Jan. 16(D) Feb. 21(D)	Interior Dep't Auditorium Interior Dep't Auditorium	Jewel Bearings Electric Relays	C. Burgess, WPB L. F. Crabtree, Auto Elec.
Wyandotte, Mich.	Instrument Society of Wayne County	D. J. McCloskey, 116 Oak St., Wyandotte, Mich.	Jan. 22(B)	West Mound Methodist Church	Electronic Potentiometer	H. H. Barnum, Brown Instrument Co.

(A) Meeting at 7:30, no dinner (B) Dinner at 6:30, meeting at 8 (C) Dinner at 7, meeting at 8 (D) Meeting at 8, no dinner

News of Societies

Editor's Note—The first five items were received too late for our December issue, which Postoffice requirements compelled to close up for the press on November 27th to be in the mails before the Christmas rush.—M. F. Behar.

November Meetings

CHICAGO

Our speaker at the November 6th meeting of the Chicago Society for Measurement and Control was Mr. C. B. Moore, President of Moore Products Co., Philadelphia. Mr. Moore gave a very comprehensive talk on all phases of the pneumatic null balance system as applied to industrial instruments. His talk began with an explanation in a very simplified way of the fundamental principles of this system. He then followed with a detailed description of the one-to-one pressure transmitter with direct system and immediately thereafter gave an interesting discussion on the detail of nozzle characteristics as displayed by a graph. Next for explanation was a one-to-one pressure transmitter using a constant nozzle-pressure differential and this was followed by a discussion of the details of the amplifying pressure transmitter as well as the high-range amplifying pressure transmitter. The differential pressure transmitter which is provided in a simple compact design was covered very thoroughly.

Mr. Moore then gave us an interesting description of the motion-transmission assembly and valve positioner.

A very interesting graph was shown on the screen which gave a representation of the control function. This was followed by a description of the various units applicable to different types of instruments and the details of the null pneumatic throttling unit, automatic reset unit, rate response unit and complete "Nullmatic" control system.

Mr. Moore's talk was followed by a very interesting discussion in which a number of questions were asked and answered by Mr. Moore.

The meeting was well attended and everyone was extremely interested in hearing a very interesting talk on a unique type of operating principle as applied to industrial instruments. —GORDON THOMASON

KANSAS CITY

At the November 21st meeting of the Kansas City Industrial Instrumentation Society, ballots for officers for the coming year were counted by tellers, R. Benninghoven (Republic Flowmeters) and W. R. Carns (Sinclair Refining). Officers elected were Wm. G. Eargle (Phillips Petroleum) *Vice President*, and Gordon H. Burke (Burke Engineering) *Secretary-Treasurer*.

H. B. Manley of J. F. Pritchard & Co., presented a basic lecture on "Practical Application of Pressure Controls." Three different methods of controlling the pressure in a tower were very well explained.

Our Quiz Kids, J. C. MacNaughton (Phillips Petroleum), H. S. Emery (Phillips Petroleum), W. R. Carns (Sinclair) and R. Benninghoven (Republic Flowmeters), had a hot time in satisfying the members as to just what various types of pressure elements were available.

Lee Lewis of Economy Equipment Co., Kansas City, introduced his guest projector operator from St. Louis, Hans Freeman of Economy Equipment Co. and the St. Louis Instrumentation Society. Hans extended greetings from the St. Louis Society.

W. H. Pugsley, Manager of Engineering, Hays Corporation, Michigan City, Indiana, presented a film and talk on combustion control. The positioning control system and metering control system were very clearly explained by the film and Mr. Pugsley. The Hays Corporation should be proud of this film and talk by Mr. Pugsley. They were both conceded a 4-star rating by our members. —W. A. REICHOW, *President*

NORTHERN INDIANA SOCIETY FOR MEASUREMENT AND CONTROL

EDUCATION — FRATERNITY — DEMOCRACY

The November meeting of the NISMC was held at Vogel's Restaurant in Hammond, Indiana, on Friday, Nov. 17th.

Mr. George A. Russ, Radiologist of the Claud S. Gordon Co., spoke on The Role of X-rays in Testing and Controlling Industrial Materials. Mr. Russ explained the theory of the X-ray and the many applications for its use. There have been many improvements in the x-ray Science since the war started. The Army and Navy have been x-raying their materials and armor plates up to 16" thick. Industry will continue to use this science more in the post war period, so as to make better products.

This meeting "hit the nail on the head" for the members of the steel and foundry groups. —KENNETH M. FRAME

PHILADELPHIA

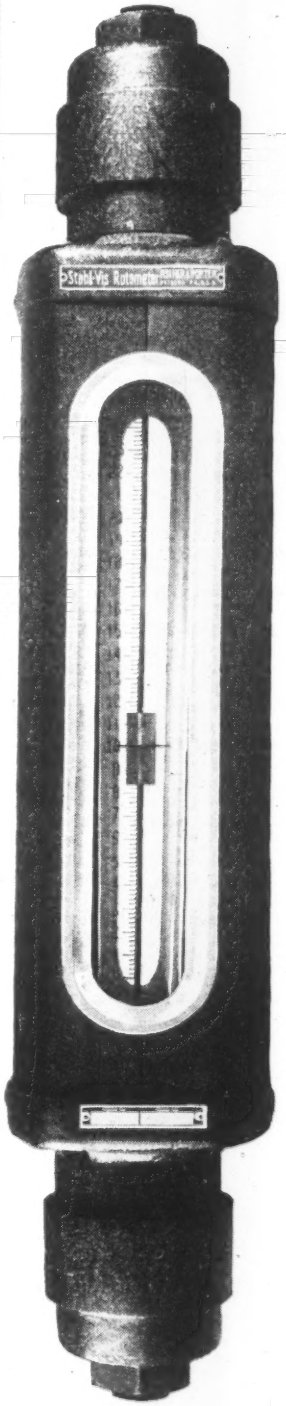
There was a large and very enthusiastic turn-out at the November 15th meeting of the Philadelphia Society for Instrumentation to hear Mr. T. A. Cohen address the membership on "Electronic Design as Applied to Automatic Control Problems." Mr. Cohen's address showed the effort and time he had put into the preparation of his material, and the membership thought his subject was very well covered.

We were surprised to learn that there were so many different types of vacuum tubes, which Mr. Cohen classified in a readily understandable chart.

He pointed out the use of vacuum-tube control in a Wheatstone bridge circuit, conversion of a.c. to d.c. in measurement of very minute a-c. voltages, the use of the electronic profilometer, the use of vacuum tubes as relays and in resonant circuits.

Mr. Cohen showed us some slides on the application of the capacitor method using

Here is the ROTAMETER with every flow-measuring feature you asked for!



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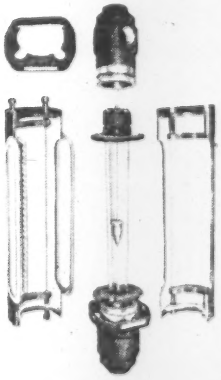
What features do you consider necessary in a rotameter to meet every requirement for accurate flow measurement? In a survey conducted by Fischer & Porter, 250 instrument engineers answered this question with sketches and suggestions. These were carefully analyzed, then combined with features suggested by our field experience, and built into the new Master Enclosed Rotameter.

The Master Enclosed Meter has strong, pressed-steel structural members that enable it to take full line strain and hard usage. Furthermore, the Operator is fully safeguarded because the rotameter tube is completely enclosed and readings are taken through safety glass panels. Universal end fittings permit horizontal pipe connections at any angle. Stuffing boxes are easily adjusted from the outside and for cleaning purposes the meter comes apart readily by removing a few screws.

The Master Enclosed Rotameter is available in all forms—indicating, recording or recording-controlling in sizes up to 4" inclusive for handling a maximum of 300 GPM of water or 400 CFM of air. Catalog 25-D gives the complete details. Obtain a free copy by writing to us on your Company letterhead.

The Master Enclosed Rotameter with screwed connections. Flanged connections are also available.



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OUTPUT VOLTAGE: Approximately 150 volts positive.

OUTPUT IMPEDANCE: 6Y6G cathode follower with 1000 ohm load.

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MISCELLANEOUS: Displaced sync output, individually calibrated frequency and pulse width dials, 117 volt, 40-60 cycles operation, size 14″x10″x10″, wt. 31 lbs.

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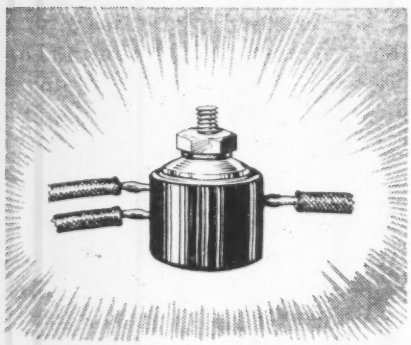

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an electron-tube circuit in measuring liquid level, both directly by submerging in the liquid and indirectly where the liquid level is in a gage glass between capacitor plates.

Mr. Cohen's thoughts on the application of electronic control might be summarized as follows:

"Automatic-control mechanisms for the control of the usual variables, such as liquid and material levels, material flow, pressure, temperature, etc., have become increasingly common, especially since the requirements of our Armed Forces have caused an increasingly acute shortage of experienced technical personnel. Although automatic-control mechanism has been quite common in process plant, recent developments involving the use of the electron tube have presented new solutions of automatic-control problems. In many cases, the electron tube has made possible a simplification of automatic-control mechanisms and, in some cases, has made possible simple solutions of control problems which were less well solved by earlier pneumatic, hydraulic, or mechanical control mechanisms. In the Process Industries, the electron tube family and its applications furnish better answers for the speeding of operations and the improvement of processes. A rapidly-expanding art encompassing the electron tube has, in a few years, taken a position of tremendous importance in process work, and as yet its vast potentialities have been barely assayed. Indeed, it is entirely probable that electronic applications in industry and laboratory may eventually overshadow the more customary usage of the electron tube in the communication fields. All manner of mechanisms known to the physicist and industrial engineer can to some extent be benefited by the use of some form of these intriguing devices. A change in a material's physical property or condition, whether chemical, electrical, mechanical, or otherwise can cause an appropriately-designed electronic mechanism to respond immediately to effect a desirable result. Because it is based for function upon the mobility of the electron, the resulting response in a properly designed electronic relay mechanism is not limited by the inertia of moving parts more common to a mechanical mechanism."

Quite a few members stayed after the meeting for a lengthy discussion with Mr. Cohen on specific applications.

Our dinner attendance was 41, while there were 96 at the meeting. —J. E. GAMBRILL

WYANDOTTE

Fifty-three members and guests attended the November 27th meeting of the Instrument Society of Wayne County, held at the West Mound Church. Several of the guests became members. There was a grand country supper, some visiting and a short business session. Then the main program. The talk on Electronics by Mr. Satullo of the University of Detroit was carefully prepared and very well delivered. The slides were very good. We all got a better understanding of electronic tubes and circuits and their use in instrumentation.

We are thinking of getting lapel buttons and will welcome any suggestions as to appropriate design, etc., or as to what other instrument societies may have done.

We are arranging with the Wyandotte Library to have some space for instrument literature. We will subscribe to *Instruments* for the Library and will buy several books and ask for catalogs from the leading instrument companies. —JOHN MACPHERSON

December Meetings

NEWARK

A sound movie, "Electronics at Work," was shown at the December meeting of the Society for Measurement and Control (N.J.). This was followed by a talk, "Electronics In Industry," given by Mr. Carl P. Bernhardt of the Westinghouse Elec. & Mfg. Co. Mr. Bernhardt used slides to illustrate some

...the applications of electronic devices that ... in use today. Although this was not a ... that was primarily about instruments, ...asurement or control entered into almost ...y application.

...everal specialized instruments were de...bed, such as the form of glossmeter that ...trols high-frequency heating in tin-plat... of steel [see *Instruments*, June 1944, ...es 328-329]. BOB GRAY

NEW YORK

The December meeting of the New York ...ciety for Measurement and Control was ...ld on the 26th with 33 present for the ...nner and an additional fifteen attending ...e meeting.

Keith Henney, Editor-in-chief of *Elec...onics*, spoke on "Pertinent Trends in In...ustrial Electronics." He explained various ...ectronic methods for measuring time ac...urately, detecting flaws in metals and other ...aterials, the use of the oscillograph, flux...graph, cyclograph and the klystron tube. ...short report on the early returns of a McGraw-Hill survey now in progress, on the ...pplication of electronics, shows wide appli...ations and growing use of electronic in...struments and devices. Many questions were ...nswered by Mr. Henney during the dis...ussion period. —H. R. KALBFLEISCH

PHILADELPHIA

The 23rd meeting of the Philadelphia So...iety for Instrumentation was held on De...ember 20, at which twenty-six were at ...dinner and sixty-five were at the meeting.

Mr. A. A. Hejduk of the Meriam Instru...ment Co., talked to us on "Manometer Ap...plications in Industry." He classified man...ometers in three types: (1) U-tube Type, (2) Pot Type, (3) Inclined-tube Type.

Without going into fundamental details on the use of manometers, Mr. Hejduk told us of several novel applications where manometers were used to determine leakage by means of pressure increase from the supply side of the system to the tested side of the system. This procedure had even been evolved to timing pressure increase as a means of determining leakage.

He described the use of inverted-U type on low flows, where the measuring fluid was the actual fluid flowing in the line. This avoided any contamination of the flowing fluid, as well as making the manometer easy to service.

The most interesting development in manometer applications which is just being made available, was the use of manometers either 50" or 100" in series, so that pressures up to as high as 500 lbs./in.^{2} could be read to inches or tenths of inches of water throughout that range, by building up the pressure on one manometer after another.

A social evening was provided for the members to enable them to meet the new officers for 1945. The new officers are:

Ted Newcomb (Gulf Oil Co.) *President;* John Johnston, Jr. (Sun Oil Co.) *Vice-President;* George E. Gress (Automatic Temperature Control Co.) Sec'y; L. John Seifert (Atlantic Refining Co.) *Treas.*

—J. E. GAMBRILL

WASHINGTON

The December meeting of the Instrument Society of Washington, held in the Interior Department Auditorium December 19, was attended by approximately 100. Instrument work in local government laboratories was the subject of the program.

Captain Harold E. Saunders, USN, Technical Director of the David W. Taylor Model Basin, spoke on "Instrument Activity of the David W. Taylor Model Basin."

Mr. D. L. Parkhurst, Chief of the Instrument Division, Coast and Geodetic Survey, spoke on "Instrument Activity at the Coast and Geodetic Survey."

This was the annual business meeting of the society and reports of the officers were received. It was announced that since the society's organization in May 1944 a total of 175 members have been enrolled. All members joining before December 31, 1944 are considered Charter Members. The pres-

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At last a gage that takes the guess work out of checking internal diameters either machine bored, or close ground and lapped. It is called the Keene Internal Gage and is the first accurate method for fast correct checking of internal splines and gears on both minimum and root diameters. The gage is ideal for machining and inspection work, and proves its value in increased production. It can be used with either a master, or micrometers.

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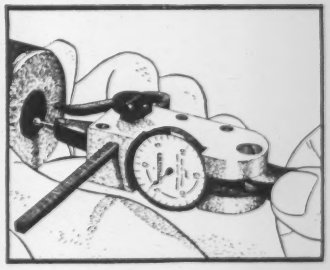
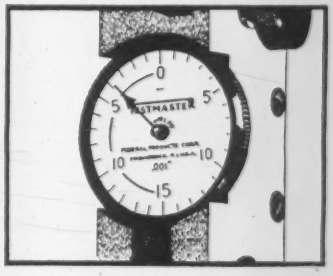


Determining correct setting for gage.



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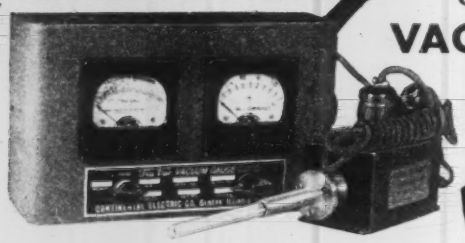

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4. Indicates vacuum changes as they occur.
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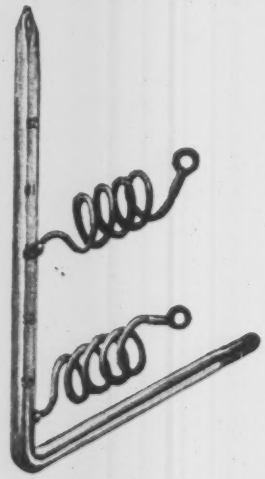

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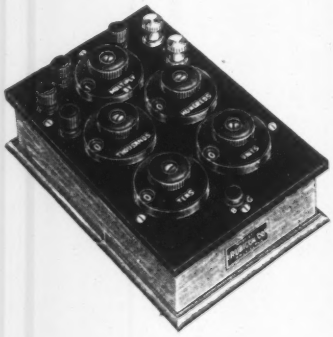

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ent officers will continue in office through 1945 as provided at the time of their election in June 1944. These are:

R. C. Darnell, *President*, Box 4730, Washington, D. C.; D. F. Windenburg, *Vice Pres.*; Wm. R. Blair, *Vice-Pres.*; W. A. Wildhack, *Corresp. Sec'y*, National Bureau of Standards; R. G. Quick, *Recording Sec'y* Raymond Morgan, *Treasurer*, University of Maryland, College Park, Md.; E. R. Schaeffer, *Councilor*; G. H. Lovins, *Councilor*, *Committee on Meetings:* E. A. Capelle Chairman; *Committee on Membership:* A H. Mears, Chairman. —R. C. Darnell

WYANDOTTE

The Instrument Society of Wayne County met as scheduled on Monday evening, December 18th at the West Mound Methodist Church. It was "Family Night." Twenty-five members with their wives or other lady guests attended. There was a period of visiting and getting acquainted, some business and a chicken dinner.

Then there were several reels of sound pictures: news, travel, and a comedy.

The President, Mr. Baker, announced a course in Industrial Electronics to be started at the University of Detroit in January. Several members will enroll in it.

Mr. Baker announced also that he will appoint a Committee on Education and Discussion, by which the experience and knowledge of all the body will be made available to each member.

—John MacPherson

Engineering Societies

The American Society of Mechanical Engineers held its Annual Meeting in New York Nov. 27-Dec. 2; the American Institute of Electrical Engineers will hold its Winter Technical Meeting in New York Jan. 22-26.

Many interesting papers on measurement and automatic-control subjects were presented at the ASME meeting and will be presented at the AIEE meeting. Two lists (necessarily incomplete) are printed below, for the benefit of *Instruments* readers who are not members and who will desire to order reprints or preprints. —MFB

Reprints and preprints are sold at various prices depending on length, etc., the majority being 15 cents or 20 cents. As we go to press we have not received schedules of prices, therefore we recommend that the average (17½ cents) be taken. In other words, if you order exactly ten reprints or preprints from the AIEE or from the ASME, enclose check or money order for $1.75 and the chances are that it will come out even or so close that the AIEE and ASME bookkeepers will not bother. (Or else, figure on a 20-cent average and add a P.S. naming the Red Cross or March of Dimes.)

Send orders to Publication Sales, AIEE, 33 W. 39th St., N. Y. 18 (ordering by assigned number); and to Publication Sales, ASME, 29 W. 39th St., N. Y. 18.

AIEE MEETING

Session on Instruments and Measurements:

45-24. Orthomagnetic Bushing Current Transformer for Metering. A. Boyajian, G. Camilli.

45-19. A Modulated-frequency System of Telemetering. H. E. Renfro, A. P. Peterson.

45-65. Dynamic Measurements on Electromagnetic Devices. E. L. Norton.

45-66. A Portable Instrument for Measuring Insulation Resistance at High Voltage. F. W. Atkinson, R. B. Taylor.

Session on Temperature Measurements and Standards:

45-32 and 45-33. Investigation of Hot-spot Temperatures in Motors. Fourteen authors.

Other Sessions:

45-69. The Resistance-coupled Amplifier. L. G. Cowles.

45-47. Tracer-controlled Position Regulator for Propeller Milling Machine. C. R. Hanna, W. O. Osbon, R. A. Hartley.

45-3. Speed Control System for an Aircraft-cabin Supercharger Drive. F. W. Godsey, J. D. Miner, Jr., O. C. Walley.

45-81. The Amplidyne Generator Applied to speed-controlled Electric Gun Turrets for Aircraft. L. A. Zahorsky.

45-5. Simulated High-altitude Testing of Aircraft Ignition Cables and Connectors. H. H. Race, A. M. Ross, Jr.

45-64. An Interval Timer for Arc Duration. J. S. Quill.

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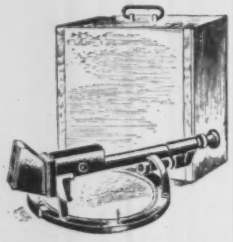

With lighthouses blacked out, shore lights dimmed, familiar landmarks lost, a ship's navigator needed a reliable new device to take bearings.

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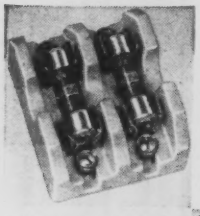

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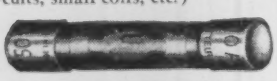

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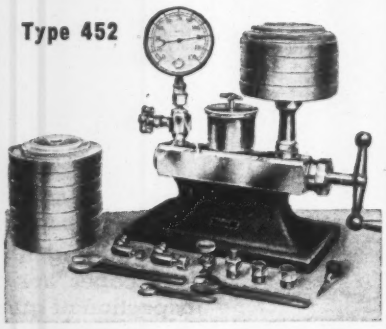

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The Type 452 is designed for simplicity and compactness. It incorporates the newest refinements and improvements. Adapters and tools are supplied, as well as either carrying case or protecting cover.

Immediate and intelligent attention will be given to your inquiries on all industrial speed measurement problems. Drop us a line today.

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45-40. Transient Response of Controlled Rectifier Circuits. P. T. Chin, G. E. Walter.

45-42. Measurements of Stray Load Loss in Induction Motors. D. H. Ware.

45-12. Measurement of the Subtransient Impedances of Synchronous Machines. Gordon F. Tracy, W. F. Tice.

45-55. Rectifier Relay for Transformer Protection. E. L. Michelson.

45-22. Damping and Synchronizing Torques of Power Selsyns. C. Concordia, Gabriel Kron.

45-27. Variable Unbalanced-voltage Control. W. R. Wickerham.

45-62—ACO. Principles of Grid Control for Thyratrons. P. H. Chin, E. E. Moyer.

ASME MEETING

Industrial Instrument Sessions:

The Coefficients of Herschel Type Cast Iron Venturi Meters. W. S. Pardoe.

Piping Arrangements for Acceptable Meter Accuracy. R. E. Sprenkle.

Remarks on On-off Control in Resistor-type Furnaces. Victor Paschkis.

An Instrument for indicating the Amount of Gas in Gas-liquid Mixtures. B. R. Walsh, G. S. Peterson.

A Pneumatic Piston Ring Gage for Radial Pressure Measurement. Paul G. Exline.

Electronic Instruments for Industrial Processes. P. S. Dickey, A. J. Hornbeck.

Symposium on Methods of Measurement of Heat Absorption in Furnaces:

The Over-all Heat Absorption of a Furnace by Measurement of Gas Weight and Temperatures at Furnace Outlet. H. F. Mulliken.

The Use of Radiation Pyrometers to Measure Distribution of Heat Intensity in the Furnace. A. A. Markson.

The Use of "Calorimeters" such as Representative Surfaces Exposed in the Furnace and Isolated from the Circulation of the Unit so That the Total Heat Absorbed May Be Measured. R. C. Patterson.

The Use of Measured Metal Temperatures and Temperature Gradients of the Tube Wall to Determine the Rate of Transmission of Heat to the Fluid. F. G. Ely, L. A. Mekler, H. H. Becker.

Introduction to Industrial Furnace Applications. Victor Paschkis.

Direct Measurement of Heat Absorption of the Charge in a Furnace. F. S. Bloom.

Correlation of Direct Measurements with Electrical Analogy. Victor Paschkis.

Conductivity of Laminated Materials. J. L. Finck.

A New Method for Determination of Fluid Velocity Distribution Applicable to the Study of Convective Heat Transfer. Alexander Kolin.

Heat Loss From Furnace Walls. A Critical Review of Measuring Techniques. C. B. Bradley.

Temperature and Quantity Measurements of Gases Leaving Furnace. R. M. Conner.

Other Sessions:

Direct Analysis of Mechanical Wave Filters. R. C. Binder.

Network and Differential Analyzer Solution of Torsional Oscillation Problems Involving Non-Linear Springs. C. Concordia.

A New Device for the Solution of Transient Vibration Problems by the Method of Electrical - Mechanical Analogy. H. E. Criner, C. D. McCann, C. E. Warren.

A Preliminary Tyndallmetric Study of Sugar Refinery Liquors. L. E. Waymouth, M. C. Miller.

Relation of Surface Roughness Readings to Actual Surface Profile. Leo P. Tarasov.

A Thermal Balancing Method and Mechanical Investigation for Evaluating Machinability. A. O. Schmidt, O. W. Boston, W. W. Gilbert.

An Acceleration Damper. Paul Lieber.

Measurement of Torque Transmitted by Rotating Shafts. B. F. Langer.

Numerical Methods for Transient Heat Flow, Lieut. Com. G. M. Dusinberre.

An Electrical Geometrical Analogue for Heat Flow. Carl F. Kayan.

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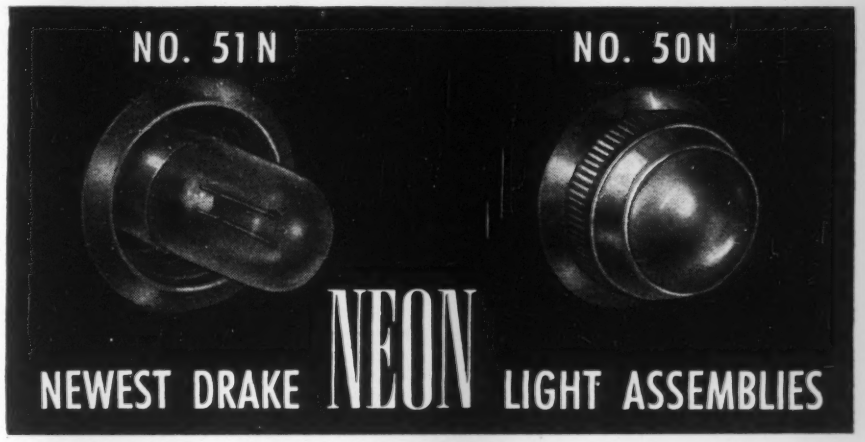

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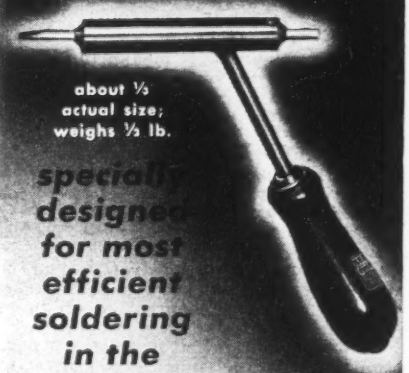

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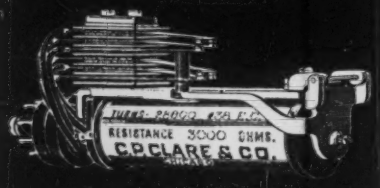

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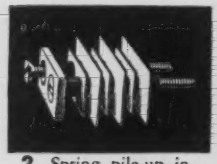

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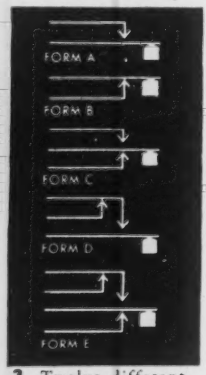

3. Twelve different standard or special types and sizes of contacts can be furnished. Contacts are overall-welded to nickel silver springs. Sizes range from .062" silver, rated one ampere, 50 watts, to .1875" tungsten, rated four amperes, 500 watts.

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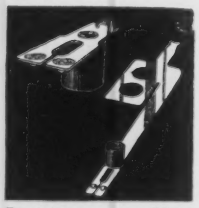

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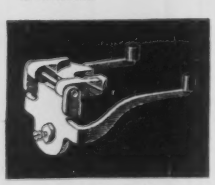

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Manufacturers New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. To assist in the War Effort we urge readers to request ONLY those bulletins which will be of value to them. Use the coupon on the facing page.

M-1 **"Electronic Pneumatic Mechanical Instrumentation."** The September-October 1944 issue of this house organ has a number of articles. Of special interest: "Fundamentals of Automatic Control"; "Maintenance of Orifice Type Flow Meters" and "Factors in Obtaining Clear, Legible Chart Records." Brown Instrument Co., 4482 Wayne Ave., Philadelphia 44, Pa.

M-2 **Supersonics for Non-destructive Testing.** 4-page 8½" × 11" Bulletin ST-99A illustrates the supersonic "Sperry-tron" for exploring the interior of solids for defects or discontinuities by measuring reflections or the transmission of high-frequency vibrations through the material being tested. Sperry Products, Inc., 1505 Willow Ave., Hoboken, N. J.

M-3 **Sapphire Gages.** 6-page 8½" × 11" catalog describes, illustrates and tabulates sapphire plug and ring gages which are claimed to outwear steel gages 50 times over. Price lists are included. Elgin National Watch Co., 932 Benton St., Aurora, Ill.

M-4 **Industrial Timer.** 4-page 8½" × 11" Bulletin 4492 gives complete details of a manually-reset interval timer which can be preset to allow a given operation to continue for any predetermined time limit; and to close or open a circuit at the end of the preset time. Paragon Electric Co., 37 West Van Buren St., Chicago 5, Ill.

M-5 **Heat & Airflow Instruments for Aviation & Industry.** 4-page 8½" × 11" Bulletin 302 describes directionally shielded total pressure tubes; pitot-static pressure tubes and pitot-static thermocouple tubes, adapted to powerplant or aeronautic experimentation. Revere Company, Wallingford, Conn.

M-6 **Test and Check Instruments.** 8-page 7½" × 10" Folder 250-444 covers thermocouple, radiation and optical pyrometers; lineman portable test set; potentiometers for measuring thermocouple emf; etc. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.

M-7 **"Millionths of an Inch for Sale."** 16-page 8½" × 11" bulletin profusely illustrates tapered plug and ring gages, concentricity gages, special plug and ring gages, profile gages, spline gages, hex plug gages, master gears, gear rolling fixtures, and optical master inspection dividing head. Vinco Corp., 8855 Schaefer Highway, Detroit 27, Mich.

M-8 **Depth, Draft, Pressure & Vacuum Gages.** 8-page 8½" × 11" folder illustrates and gives specifications of these instruments manufactured by Uehling Instrument Co., 471 Getty Ave., Paterson, N. J.

M-9 **Dynamic Balancing Machines.** 20-page 8½" × 11" loose-leaf folder covers small bench size as well as heavy duty static and dynamic balancing machines. Illustrations of many models are included. Bear Manufacturing Co., Rock Island, Ill.

M-10 **Automatic Metering & Waste Valve.** 2-page 8½" × 11" Bulletin 960 describes this valve for water supply lines to unheated areas, especially to spray nozzles. The new type valve provides two services in one compact assembly—it offers an automatic drain to prevent freezing, and at the same time provides metering means. Alco Valve Co., St. Louis 5, Mo.

M-11 **"Precise Production."** The 107th issue of this house organ is devoted to applications of the Magni-Ray (an illuminated magnifier) in various industries. George Scherr Co., Inc., 200 Lafayette Street, New York 12, N. Y.

M-12 **Water Gages & Columns.** 8-page 8½" × 11" folder illustrates a number of gages and water columns for a maximum of 300 lbs. working steam pressure at 450°F. Ernst Water Column & Gage Co., Livingston, N. J.

M-13 **Electrical Signals.** 104-page 8½" × 11" Catalog 61 is a guide to good signaling which helps the buyer in selecting the proper type of signal. It contains helpful engineering data and wiring diagrams. Other features of catalog are tables of electrical characteristics which are so set up that they are literally an index for one who is seeking a signal of a certain resistance. Faraday Electric Corp., Adrian, Mich.

M-14 **"The CD Capacitor."** The September issue of this house organ has a feature article "Servicing L-f. Amplifiers" while October issue has one entitled "Radio Theory Review—for FCC Operator Exams." Cornell-Dubilier Electric Corp., Hamilton Blvd., South Plainfield, N. J.

M-15 **Flow Detector.** 4-page 8½" × 11" Bulletin 91-B illustrates an electric flow detector for the inspection of ferrous and non-ferrous tubing and bar stock. Illustrations of a number of defects are included. Sperry Products, Inc., 1505 Willow Ave., Hoboken, N. J.

M-16 **"The Hydromike."** The October issue is devoted to measuring sewage. Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland 13, Ore.

M-17 **Master Inspection Dividing Head.** 2-page 17" × 22" folder illustrates this instrument for inspection and final checking of the spacing, angular locations and similar characteristics of gear teeth, master index plates, splines and peripheral gears. Vinco Corp., 8855 Schaefer Highway, Detroit 27, Mich.

M-18 **Combustion Controls.** 4-page 8½" × 11" folder illustrates a draft control, damper program control, draft gage, pressure gage, flue gas temperature indicator and an actuator. Perfex Corporation, 455 W. Oklahoma Ave., Milwaukee 7, Wis.

M-19 **Photogrammetric Equipment.** 24-page 8½" × 11" bulletin covers mapping and aerial cameras, contact printers, timers for mapping, stereoscopes, height finders, plotters and direction finders. Abrams Instrument Co., 602 Shiawassee St., Lansing, Mich.

M-20 **Sequence Relays.** 2-page 8½" × 11" catalog sheet illustrates, describes and lists four thermal-timer type sequence relays, Series 107000, all with 15-second time interval, with main-contact ratings of 0.02, 3 and 6 amperes. Instrument Div., Thomas A. Edison Inc., West Orange, N. J.

M-21 **Food-locker Temperature Recorders.** 2-page 8½" × 11" Form 98067 i-

illustrates and describes Locker Room thermometer—mandatory in some states and advantageous for food preservation everywhere. Taylor Instrument Companies, Rochester, N. Y.

M-22 **Program Timer.** 1-page 8½" × 11" announcement describes "Model P5-4" with 24-hour schedule, for time signals or reminders in factories, airports, schools, etc. Zenith Electric Co., 152 W. Walton St., Chicago 10, Ill.

M-23 **Aircraft Electrical Instruments, etc.** 8-page 8½" × 11" bulletin describes indicating type indicators for resistance thermometer elements, including an aircraft-engine Gage Unit having three indicators in one housing; also remote pressure transmitters and indicators, fire detection system, sealed thermostats and thermal timing relays. Instrument Div., Thomas A. Edison Inc., West Orange, N. J.

M-24 **"Cenco News Chats."** The 20-page December issue of this house organ has a biography of A. A. Michelson as a feature article. Other items describe new developments in laboratory instruments and apparatus. Central Scientific Co., 700 Irving Park Road, Chicago 13, Ill.

M-25 **Temperature Control.** 4-page 8½" × 11". Bulletin 441T describes the Type W Thermostat for the control of electric devices between temperatures of —120° and 600° F. Units have an approximate differential of ½° to 1° F. in liquids, subzero testing cabinets and mechanical convection ovens, and 2°F. in gravity type ovens. United Electric Controls Co., 76-71 A Street, Boston 27, Mass.

M-26 **Aviation Heat & Airflow Instruments.** 4-page, 8½" × 11". Bulletin 302 illustrates Pitot-static pressure tubes, static-Pitot temperature probes, static pressure tubes and Pitot pressure tubes. Revere Company, Wallingford, Conn.

M-27 **Corrosion Protection.** 12-page 6" × 9" bulletin describes a recent development, Protek Plugs which contain a dehydrating agent, silica gel, impregnated with anhydrous cobalt chloride. The gel thus treated is bright blue when active and dry, reaching a pink color upon complete saturation. These plugs are used to prevent rust in aircraft instruments and other devices. Chandler-Evans Corp., South Meriden, Conn.

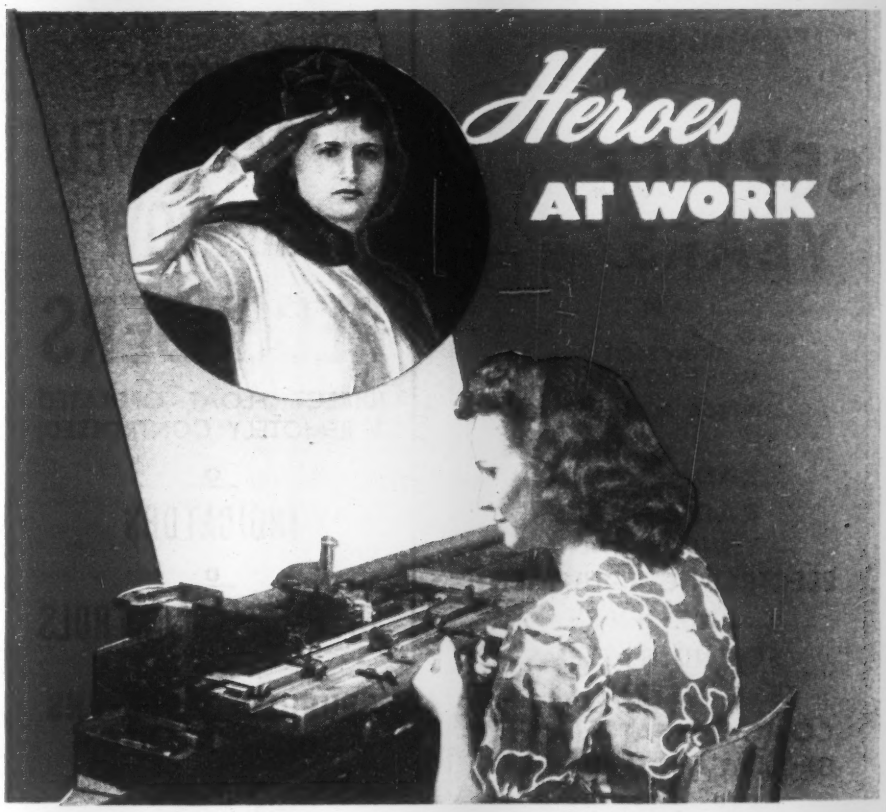
M-28 **"Wheelco Comments."** The November-December issue of this house organ has two articles: one describing the applications of automatic temperature control to the burning of porcelain ware in an art gallery and the other describing a commercial heat treating plant. Wheelco Instruments Co., Harrison & Peoria Sts., Chicago 7, Ill.

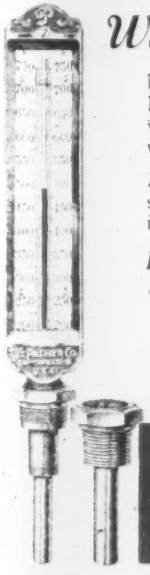
M-29 **Precision Gage Blocks.** 4-page 8½" × 11" bulletin describes and lists various sets of gage blocks, states guaranteed accuracies, gives prices. Suro Mfg. Co., 65 Greyrock Place, Stamford, Conn.

M-30 **"Purging" Controlled Atmosphere Furnaces.** 8-page 8½" × 11" reprint of an article which describes the application of the "Ranarex" recorder to this application. Permutit Co., 330 West 42 St., New York, N. Y.

M-31 **X-ray Diffraction Apparatus.** 12-page 8½" × 11" booklet describes the apparatus and applications. Diagrams, typical diffraction films, and several tabulations are given in order to show how the equipment is used for identification, research and production. North American Philips Co., Inc., 100 East 42 St., New York, N. Y.

M-32 **Hydrogen Ion Determination.** Five 8½" × 11" catalog sheets describing a photoelectric hydrogen ion device which is used in industry to control the acidity and alkalinity of solutions independent of human judgment and of light conditions. The last sheet (No. 509) gives transmission-versus-pH curves of ten indicator solutions covering full range from 0 to 14. Photovolt Corp., 95 Madison Ave., New York 16, N. Y.





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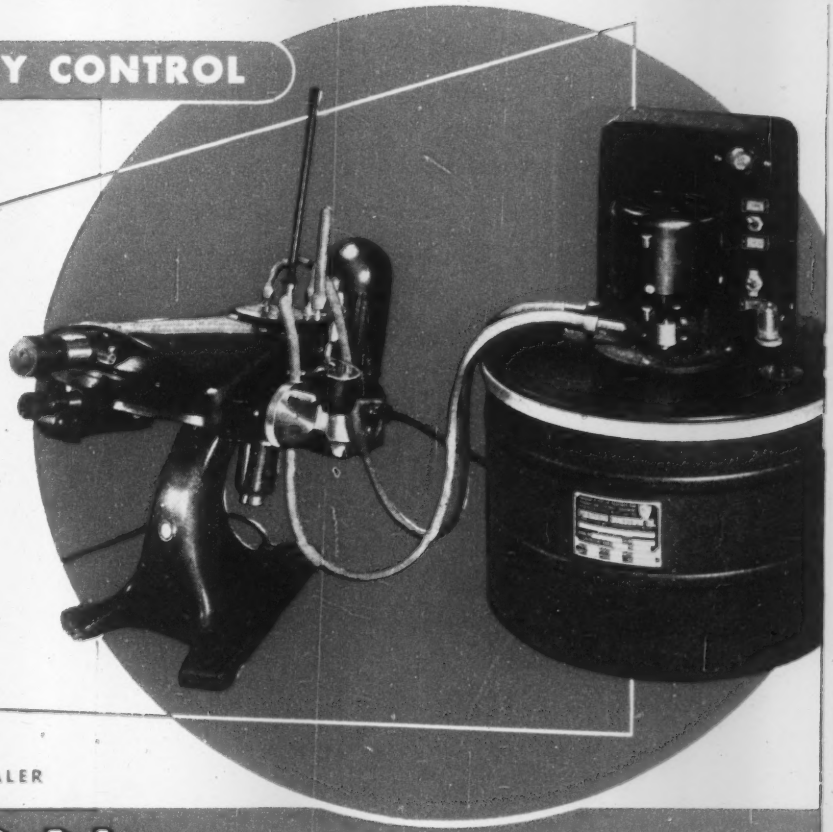

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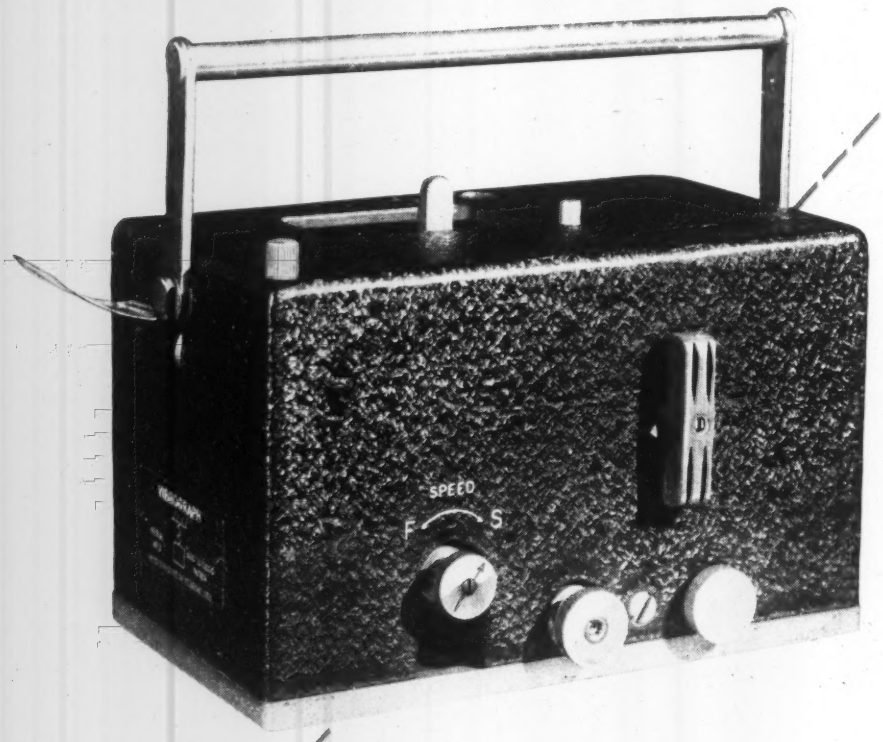

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